Five Years Questions and Answers

National Association of Stationary Engineers

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STATIONARY ENGINEERS

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PREFACE

THE Questions and Answers found herein were first published in the *National Engineer* in a competitive educational course, designed to stimulate technical work and theory study among the members of the National Association of Stationary Engineers.

This volume becomes the fourth bound edition of the same, which represents the work of separate committees acting through a period of five years. These committees were as follows:

1896-1897

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For 1896-7: Ohio No. 36, Cincinnati; Iowa No. 8, Sioux City, and Illinois No. 22, Rockford.

For 1897-8: Ohio No. 15, Cincinnati; Illinois No. 22, Rockford, and Iowa No. 8, Sioux City.

For 1898-9: Iowa No. 8, Sioux City; Louisiana No. 1, New Orleans, and Massachusetts No. 17, Lowell; and also J. S. Gillespie, Pennsylvania No. 12, Philadelphia, and H. H. Garman, Ohio, No. 28, Akron.

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For 1900-01: Massachusetts No. 17, Lowell, and Massachusetts No. 16, Waltham.

Volumes I, II and III, containing the problems for the years 1896-7, 1897-8 and 1898-9, were edited by Chas. Desmond, at that time editor of the *National Engineer.*

This volume is presented by the undersigned committee in the role of editors, who ask your kind indulgence for their effort, expressing their thanks to the several past committees for assistance in handling the proofs, and hopeful that the book may attain its object, which is to be of service as a guide and reference to the practical student-engineer.

The sequence of the questions and answers by years has not been respected in the present arrangement, which attempts to classify the several problems under their logical headings. The result has not, however, been entirely satisfactory because the questions were originally presented without any particular thought of their ever becoming a part of an harmonious whole. A large demand for the book will, if it comes, assure the committee that its work has been fairly well done.

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NATIONAL ASSOCIATION OF STATIONARY ENGINEERS

QUESTIONS *and* ANSWERS

1896–1901

Boilers, Furnaces, Fuel, Combustion, Chimneys, Etc.

Q. 1. (1896-7.) What causes worst form of external corrosion of steam boilers?

Ans. 1. External corrosion is frequently formed by exposure of the shell to the cold air. Is more likely to occur when cold than when under pressure and moisture condensing on it when cold aids in formation of rust. It is likely to occur along line of brick work in externally fired boilers.

Leaky joints are another source of corrosion, either from riveted seams, man or hand holes, or from imperfectly fitted attachments. Certain coals are rich in sulphur, the products of whose combustion contain sulphurous and sulphuric acid—this has a bad rusting effect on boilers. [Wet ashes or soot, when permitted to remain in contact with the boiler plate, cause corrosion.]

Q. 2. (1896-7.) Give safe strain for braces in steam boilers.

Ans. 2. For iron 6,000 lbs., for steel 7,000 lbs. per square inch cross-section.

Q. 3. (1896-7.) Does heat or pressure cause greatest strain in boilers?

Ans. 3. Heat, on account of unequal expansion.

Q. 4. (1896-7.) How to construct a tubular boiler to insure free circulation?

Ans. 4. To insure free circulation in horizontal tubular boilers of the ordinary type the tubes must not be staggered but disposed in straight vertical lines. The spacings between tubes should be ample

and a clear space of 4″ to 6″ is proper between the outer row of tubes and the sides of the boiler shell, together with a space from 14″ to 16″ at the bottom. The upper row of tubes to be well covered when the water line is carried at a point a little above 2/3 of the shell diameter. Some designers prefer omitting the center row of tubes or modifying the space to allow more freedom of the circulating currents at that point.

Q. 6. (1896-7.) Name the cheapest and most commonly used scale preventer.

Ans. 6. Taking the country as a whole, sal-soda is the cheapest and most commonly used. The Eastern section is, however, using kerosene oil to a great extent.

Q. 7. (1896-7.) For best results in tubular boiler with natural draft, give ratio between grate and heating surface.

Ans. 7. This would depend on the amount of draft and the kind of coal used. Slack coal requires a larger grate surface than lump coal. Also when the draft is strong the grate area does not need to be so great as when draft is poor. All chemists appear to agree that the perfect combustion of one pound of coal gives exactly the same number of heat units, as the perfect combustion of another pound of the same coal. The question would then appear to resolve itself into the question, whether we can get nearer the perfect combustion with strong draft and with small grate surface, or with a moderate draft and large grate surface. Ratios vary from 30:1 to 60:1. Probably 45:1 is the best ratio.

Q. 11. (1896-7.) What is pitting? How caused?

Ans. 11. Pitting is conical or spherical depressions which are filled with a yellowish brown deposit, consisting mainly of peroxide of iron. Pitting is caused by the action of oxygen which has been held in solution by the water, its action is hastened by the presence of carbonic acid gas which is liberated when the temperature of the water is increased. Boilers that are kept lukewarm, and in which the circulation is poor, are most likely to be affected by pitting.

Q. 14. (1896-7.) Is a "mysterious gas" formed in boilers at times of explosion?

Ans. 14. Its existence has not yet been proved, although some believe there is such a thing.

Q. 17. (1896-7.) Give relative values of solid boiler plate, double-riveted and single-riveted joints; who established them?

Ans. 17. Solid plate 100 %, double riveted 70 %, single riveted 56 %, by Sir Wm. Fairbairn. [These values are not often found in practice.]

Q. 20. (1896-7.) What advantages do water tube boilers possess over other types?

Ans. 20. Water tube boilers have the following advantages over other boilers:

1. Thin heating surface in boilers.
2. Joints removed from the fire.
3. Complete combustion.

4. Large draft area.
5. Thorough absorption of heat.
6. Efficient circulation of water.
7. Quick steaming.
8. Freedom of expansion.
9. Safety from explosions.
10. Ease of transportation.
11. Ease with which they can be repaired.

[Some of these statements are questionable.]

Q. 21. (1896-7.) If a boiler evaporates 3,000 lbs. of water per hour, what should be size of safety valve? (Pop or lever.)

Ans. 21. Rankine says the constant .006 × the water evaporated per hour = the square inch area of the required safety valve. Then, .006 × 3,000 = 18″ area and 4.8″ for the diameter of valve needed.

The Commission of United States Supervisors say the constant shall be .005. Then, .005 × 3,000 = 15″ area or 4.375″ diameter of valve.

Taking it that one square foot grate surface will burn 12 lbs. of coal per hour and that each pound of coal will evaporate 8½ lbs. of water, then 12 × 8½ = 102 lbs. of water will be evaporated per hour per square foot grate surface and 3,000 ÷ 102 = 29.4 sq. ft. grate surface required. With the ratio of one square inch of safety valve opening (pop valve) to every 3 square feet of grate surface we have 29.4 ÷ 3 = 9.8 sq. in. required in valve; or a diameter of 3.53″.

With a ratio of one square inch of valve opening (for lever valve) to each 2 sq. ft. of grate surface we have 29.4 ÷ 2 = 14.7 sq. in. of area in valve or a diameter of 4.32″.

If the boiler pressure had been given the calculation would be made on the basis that the number of pounds of steam that will flow through an orifice ot one square inch area in one second may be found by dividing the absolute pressure by 70. The following formula is also sometimes used:

$$\text{Area valve} = \frac{\tfrac{1}{2}\text{ water evaporated per hr.}}{\text{Steam pressure plus 10.}}$$

Working on this formula with assumed pressures as below:

$$\text{50 lbs. B. P.} = \frac{1500}{50+10} = 25 \text{ sq. in. area} = 5.65'' \text{ diameter.}$$

$$\text{100 lbs. B. P.} = \frac{1500}{100+10} = 13.6 \text{ sq. in. area} = 5.17'' \text{ diameter.}$$

$$\text{150 lbs. B. P.} = \frac{1500}{150+10} = 9.37 \text{ sq. in area} = 3.46'' \text{ diameter.}$$

Q. 22. (1896-7.) Should horizontal externally fired boilers be set ıevel or with a pitch? If with a pitch, which end should be the lower, and why?

Ans. 22. First: with a pitch. Second: back end. Third: to facilitate the draining of the boiler and the blowing out of mud, also have more heating surface directly exposed to fire, and as a safeguard to the water column by keeping more water at the back than is indicated in the front end of boiler.

Q. 23. (1896-7.) Name in order of general merit the four most commonly used boiler metals.

Ans. 23. Steel, wrought iron, copper, cast iron.

Q. 25. (1896-7.) What should be the temperature of gases in an uptake, for the best economy, with natural draft and a gage pressure of 60 lbs.?

Ans. 25. Theoretically same as temperature of the steam; or 307° F.; in practice from 50° to 75° or sometimes 100° greater than this, influenced somewhat by draft.

Q. 29. (1896-7.) How many tons of air are needed to burn one ton of average coal?

Ans. 29. Theoretically about 12 tons, but in practice 18 to 24 tons of air. (One pound of coal requires 12 to 24 lbs. air to burn it.)

Q. 32. (1896-7.) Can smoke once formed be burned.

Ans. 32. Yes and no. As a chemical process it can be done, but practically, in a boiler furnace, we think not. [Carbon from a hydrocarbon is the sole source of smoke; heated to 800° or upwards, it will combine with the oxygen of the air, if present in sufficient quantity, and smoke will be prevented in the furnace or consumed if such conditions can be obtained in the combustion chamber of a boiler setting.]

Q. 40. (1896-7.) What should be the pitch of rivets to give the best possible percentage of strength, in a staggered double-riveted lap joint; thickness of plate, 5/16"; diameter of rivet, 11/16" tensile strength of plate, 55,000 lbs.; shearing strength of rivet, 38,000 lbs.?

Ans. 40. In a riveted joint of the character indicated the strain transmitted by the load carried on that part of the structure represented by a distance equal to the "pitch" is resisted by the shearing strength of two rivets.

The cross section of a single rivet 11-16" diameter is .3712 square inches; hence the strength of the joint, as far as the riveting is concerned, is found by doubling the area and multiplying by the assumed shearing strength or value of the metal per square inch of section, viz.: $2 \times .3712 = .7424 \times 38{,}000 = 28{,}211.2$.

The best possible percentage of strength in any riveted joint is realized when the resistance of the unimpaired plate section between the rivets is equal to the strength of the rivets. To obtain this result the centers of the rivets must be proportioned so that the thickness of the metal, taken in inches, its tensile strength per square inch and the length of the effective section remaining between the rivets, when taken together as factors, produce a product representing a sectional value for the plate equivalent to that found for the rivets.

The decimal equivalent of 5-16", the thickness given, is .3125, which, multiplied by 55,000, its tensile strength, gives 17,187.5.

The value of the third factor is unknown; therefore, considering the conditions in hand in the form of an equation, we have: The resistance of the rivets, as previously found, 28,211.2, giving $28{,}211.2 = 17{,}187.5 \times D$, D representing the unknown factor, from which we deduce by transposing: $D = 28{,}211.2 \div 17{,}187.5 = 1.641$ inches. Since D, or 1.641, represents the distance between rivet holes, the actual pitch is one diameter of the rivet more, or $1.641 + .687$, or 2.328 inches.

Q. 41. (1896-7.) If a boiler evaporates 5,000 lbs. water per hour from and at 212°, how many HP. will it be rated?

Ans. 41. Horse-power is strictly a measure of work; the term is conventionally used to express the capacity of boilers.

Since the actual power that may be developed by any given volume of steam depends upon conditions foreign to the generator producing it, it is essential that we assume a "base" or arbitrary standard in connection with the expression by which the relative capacities of different boilers may be intelligently known, without reference to the duty actually performed thereby. An evaporation equivalent to 30 lbs. of water per hour taken from a feed temperature of 100° F. into steam at 70 lbs. gage pressure, as fixed by a board of experts during the Centennial Exposition in 1876, is generally accepted as the unit expressing the capacity of steam boilers in horse-power.

The conversion of one pound of water into steam, under the conditions specified, is effected by the absorption of 1,110 thermal units of heat, which is equivalent to the evaporation of $1110 \div 966 = 1.149$ lbs. at a temperature of 212° as required. Using 1.149 as a factor and multiplying the same by 30 gives 34.47, which represents the weight of water that may be changed to steam, from and at 212°, by the same number of heat units required to effect the evaporation of 30 lbs. of water at 100° into steam at 70 lbs. gage pressure.

The quantity 34.37 is usually assumed at 34.5 lbs., hence on the basis we have noted the direct answer to the question may be found by dividing the total amount evaporated by the boiler by the number which represents the evaporation required for one horse-power, giving: $5000 \div 34.5 = 144.92$ HP. [At the meeting of the A.S.M.E. a boiler HP. was defined as 34.5 lbs. water evaporated per hour into steam, from and at 212°, equivalent to the transfer of $34.5 \times 965.7 = 33{,}317$ B.T.U. per hour. See part of Ans. 65 (1896-7).]

Q. 42. (1896-7.) Where should the feed water enter the boiler and how be distributed, in the best practice, and for the best results?

Ans. 42. A prominent authority recommends the introduction of the feed pipe at the front head, just above the upper row of tubes, and extending along the side of the boiler nearly to the back head. It then crosses to the opposite side of the shell, and, turning downward, discharges between the shell and the tubes. [If pipe is too large it will fill with scale until force of water is sufficient to prevent the further formation of scale.]

There are strong arguments in favor of introducing the feed water into the steam space in the form of a spray, this preventing in a great measure the formation of a hard scale in the lower parts of the boiler.

In any case the comparatively cool feed water should not be allowed to come into contact with the hot part of the shell that is over the fire.

It is calculated that if a plate be cooled 200° a longitudinal strain of 8,000 lbs. to 10,000 lbs. per square inch is produced. This, in addition to the normal strain of the steam pressure, may tax the seams beyond their elastic limit.

By the same authority it is given out that girth seams develop leaks and cracks in 99 cases out of every 100 in which the feed discharges directly upon the fire sheets.

Feeding througn the blow-off or the mud-drum is not considered good practice.

Q. 43. (1896-7.) What part or parts of a horizontal externally fired boiler are subjected to greatest strains in working?

Ans. 43. The furnace sheets and seams over or near the fire or bridge wall and the back head or tube sheet, brought about through unequal expansion or contraction. Frequent and unnecessary opening of flue doors will effect front head and flooding the boiler with cold feed water may start local strains.

Q. 46. (1896-7.) Sketch to a scale of ⅛ size, the head of a 48″ tubular boiler, showing the thirty 4″ tubes, and a 4″ × 6″ handhole properly placed.

Ans. 46. See cut on following page.

Q. 47. (1896-7.) If one lb. of coal will evaporate 10 lbs. water from and at 212° F., how many pounds will it evaporate from 80° into steam at 310°?

Ans. 47. The total heat of steam is, at all temperatures, separable into two parts—latent and sensible heat. The sensible heat is that indicated by the thermometer, and it varies as its pressure. The latent heat—absorbed in converting water into steam—is by far the greater portion of the total heat. Thus, steam at a temperature of 212° F. has a total heat of 1178.6 units, so that in evaporating one pound of water at 212° into steam of 212° we have added $1178.6 - 212° = 966.6$ units; to evaporate 10 lbs. we have $10 \times 966.6 = 9666$ units. The total heat of steam at 310° is 1208.5, from which we subtract the temperature of the water, and the remainder will be the units of heat required to evaporate one pound of water from 80° into steam at 310°.

$1208.5 - 80 = 1128.5$, and as we have 9666 units to apply, then $9666 \div 1128.5 = 8.56 +$ pounds of water.

Q. 50. (1896-7.) A ten-pound piece of iron is left in the gases of a chimney until thoroughly heated and then inserted in 100 lbs. of water at 50° F. The resulting temperature of the water and submerged iron is 55°. Required: The temperature of the chimney gases.

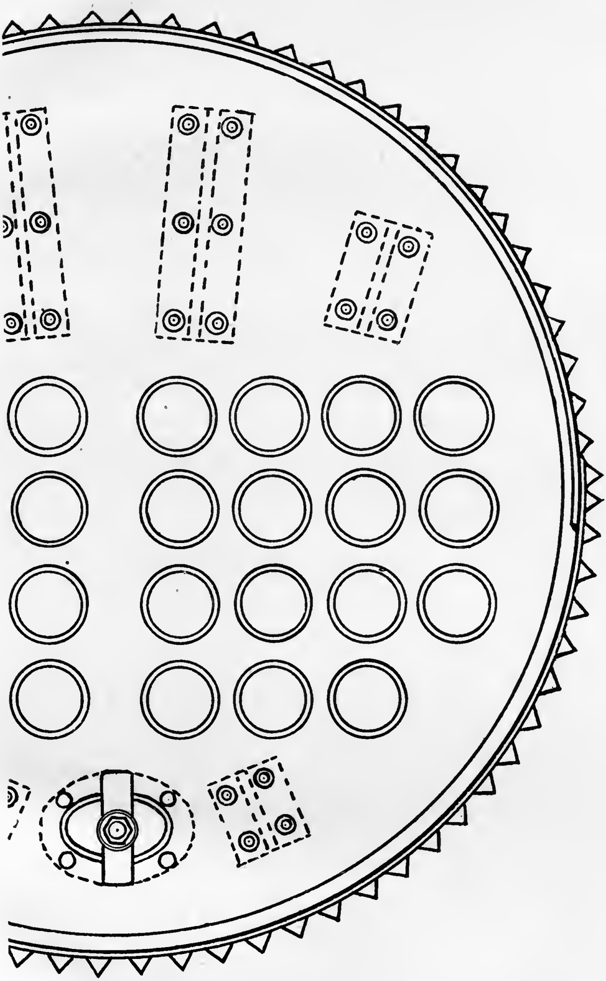
Ans. 50. One hundred pounds of water has been raised 5° in temperature; this will require 500 units of heat, which must be taken from the ten lbs. of iron in reducing its temperature from that of the chimney gases to 55° F. The specific heat of wrought iron is .1138, which is the amount of heat it will be necessary to put into 1 lb. of iron to raise its temperature 1°, or the amount of heat that 1lb. of iron will give up in failing 1° in temperature. Therefore, 10 lbs. of iron will give up 1.138 heat units for each degree drop in temperature, then $500 \div 1.138 = 439°$ fall of temperature, and $439 + 55 = 494°$ F. as the temperature of the chimney gases in the supposed case.

Q. 63. (1896-7.) Name five things or conditions upon which the efficiency of boiler heating surfaces depend.

Ans. 63. 1. Difference in temperature between two sides of the plate.
2. Thickness of plate.
3. Thermal conductivity of plate.
4. Cleanliness of surfaces inside and out.
5. Circulation of water in boiler. [Position of the surface in relation to the source of heat. Angle at which the heat rays strike the surface.]

Q. 64. (1896-7.) If a patch is to be put on the fire sheet of a tubular boiler, would you put it inside or outside, and why?

Ans. 64. A patch should always be put on the inside of the fire sheet; if put on the outside it makes a place for sediment to gather, causing the patch itself to be injured by the action of the fire. Internal



SECTION OF BOILER HEAD SHOWING ARRANGEMENT OF TUBES AND BRACES

pressure will hold the patch in place and not have a tendency to blow it off the boiler, as would be the case were it external. The calking area is reduced by putting the patch on the inside. In case the patch comes at the edge of the plate it will be necessary to let it come on the outside of the adjacent plate on account of the difficulty in making a tight joint if it was on the inside of both plates.

Q. 65. (1896-7.) Which is the more accurate way of measuring the HP of a boiler, by amount of water it will evaporate in a given time, or the number of sq. ft. of heating surface it contains? Give reasons.

Ans. 65. In measuring the horse-power of a boiler it is advisable to assume a set of practically attainable results in average good practice, and to take the power so obtainable as a measure of the power of the boiler in commercial and engineering transactions.

The unit generally assumed has been the weight of steam demanded per horse-power per hour by a fairly good engine. The magnitude has gradually been decreasing since the early times of the steam engine.

In the time of Watt, one cubic foot of water per hour was thought fair; at the middle of the present century, 10 lbs. of coal was a good figure, and 5 lbs., commonly equivalent to about 40 lbs. evaporation, was allowed for the engine.

After the introduction of the modern form of the engine the last figure was reduced 25%, and the most recent developments have still lowered this consumption of fuel and steam.

By general consent the unit has now become 30 lbs. of dry steam per hour per horse-power, which represents the performance of a good non-condensing engine. Large engines, with condensers and compounded cylinders, will do better.

A committee of the A.S.M.E. recommended 30 lbs. of water as a unit of boiler power, and this is now generally accepted. They advised that the commercial rating be taken as an evaporation of 30 lbs. of water per hour from a feed temperature of 100° F. into steam of 70 lbs. gage pressure, which may be considered to be equal to 34.5 units of evaporation; that is 34.5 lbs. of water from a feed temperature of 212° into steam at same temperature. This standard is equal to 33,305 B.T.U. per hour.

A boiler may have a large heating surface and not be as efficient as one with less. Some parts of heating surfaces are more effective than others, and the horse-power per square foot of heating surface will vary largely. Therefore we think the proper way of rating a boiler is by the amount of water it will evaporate in a given time. Square feet of heating surface is no criterion by which to judge different styles of boilers, but when an average rate of evaporation per square foot for any boiler has been fixed upon by experiment this becomes a more convenient way of rating the power of other boilers of the same style.

Q. 69. (1896-7.) Is scale, or deposit, in any quantity, a good thing in a steam boiler? Why?

Ans. 69. A light film of scale is believed to be desirable in a steam boiler. It is well known that a free contract of pure water is destructive to boiler plate. The same may be said of the acids and other chemicals commonly introduced with the feed and liberated by the action of heat. The action of such corrosive influences is believed to be materially checked by the interposition of a thin film of scale. Some think that a light scale prevents, in a measure, the leakage that would occur at seams of a poorly built boiler.

Q. 71. (1896-7.) If a boiler is to carry a working pressure of 105 lbs. with double riveted longitudinal seams of 70 per cent strength, and using a factor of safety of 5, having 60,000 lbs. tensile strength of plate, with inside diameter of shell 60", what should be the thickness of the plates?

Ans. 71. To find the thickness of boiler plates we are given the following formula:

$$T \times S \times .70 = P \times R \times F.$$

When T = thickness of plate in inches.
S = tensile strength of plate.
.70 = percentage of strength of joint.
P = pressure in pounds per square inch.
R = radius of boiler shell in inches.
F = factor of safety.

Transposing above formula we have:

$$T = \frac{P \times R \times F}{S \times .70} = \frac{105 \times 30 \times 5}{60000 \times .70} = \frac{15750}{4200} = .375 = \tfrac{3}{8}''$$

or thickness of plate required.

Q. 84. (1896-7.) How many feet of rod needed to put three guys on a smoke stack, if fastened 55 ft. above the ground and inclined at an angle of 45°?

Ans. 84. At a height of 55 ft. above a base line a line is drawn to an angle of 45° from the vertical line and a line drawn from this point at this height at this angle would pass through a point 55 ft. on the base line from its intersection with the vertical. We have a right angle triangle with 2 equal sides. To find the hypothenuse. This equals the square root of the sum of the squares of the two sides or the $\sqrt{55^2 + 55^2} = \sqrt{3025 + 3025} = \sqrt{6050} = 77.78 +$ft., which is the hypothenuse or slant side. There are three guys, then $3 \times 77.78 = 233.34$ ft. = the length of the guy rod needed, making no allowance for eyes, links, or fasteners.

Q. 89. (1896-7.) Is the use of the steam jet as an auxiliary to furnace combustion economical?

Ans. 89. A committee of experts in St. Louis in 1891, after 39 tests by various methods, report that in one case fuel consumption was increased 12% for the same work. Prof. Landreth then said "Steam jets to draw air in or inject air into the furnace above the grate and also to mix the air and combustible gases together form an efficient smoke preventer, but one liable to be wasteful of fuel." From above and also from our own experience we incline to the opinion that, generally speaking, in ordinary practice, a jet of steam above the grates will not increase the efficiency of a boiler as a steam generator.

Q. 90. (1896-7.) Given a lever safety valve: Weight of ball 90 lbs., distance from center of weight to fulcrum 40.41", weight of lever and valve 11¾ lbs., distance from fulcrum to center of gravity of lever 18", from fulcrum to center of valve 4", and diameter of valve 3½"; at what pressure will it blow off? Explain.

Ans. 90. The length of lever being 40.41" and multiplying this by 90 lbs., or the weight of the ball, will give 3639.9, or the moment of force or leverage of the ball; to this add the weight of the valve-stem and valve, or the weight of the valve-stem, lever and valve, by its fulcrum distance, or $11\tfrac{3}{4} \times 18 = 211.5$, this sum $+3639.9 = 3848.4$, gives the total moment tending to hold the valve down, against which we have a cer-

tain pressure trying to force valve up. As the valve is 3½″ diam. its area is 9.621 sq. in., which multiplied by 4″, its leverage, gives 38.484 as its leverage moment. This divided into the total downward force 3848.4 gives 100 lbs. as the pressure needed to balance the valve. Practically a little more would be needed to make the valve blow off.

Q. 93. (1896-7.) A tubular boiler has an inside diameter of 60″, and is to carry a working pressure of 105 lbs. by the gage; longitudinal seams are double-riveted, 70% strength of joints, plates ⅜″ thick, factor of safety being 5, what should be the tensile strength of plates? How found?

Ans. 93. Formula: $$\frac{R \times P \times 5}{T \times S} = \text{ts.}$$

Where R = radius in inches.
P = pressure in lbs. per sq. in.
5 = factor of safety.
T = thickness of sheets in inches.
S = strength (efficiency) of joint.
ts = tensile strength.

$$\therefore \frac{30 \times 105 \times 5}{.375 \times 70\%} = \frac{15750}{.26250} = 60000 \text{ ts.}$$

NOTE: These lectures to be used in explanation of Questions 1 and 20 inclusive of 1897-8 series.

BOILER AND FURNACE.

The efficiency of the furnace and boiler is always directly dependent upon the care, skill and knowledge of the engineer. If he properly handles the coal and regulates the supply of air, the coal produces the maximum amount of heat of which it is capable and the boiler absorbs the greater part of the heat produced and uses it in the production of steam; if he does not properly regulate the supply of coal and air, either the maximum amount of heat is not produced, or, if produced, the greater part is carried up the chimney with the gases and is radiated, or both these sources of loss occur at the same time.

A good quality of coal should produce about 14,000 heat units per pound, when properly burned, and may generate as little as 3,500, when improperly burned (Ans. 1 and 2). Of this heat the boiler should absorb from 60 to 80 per cent, and use it for making steam. (Ans. 10.)

Suppose one had 50 pounds of gases passing up the chimney per pound of coal burned, and these gases were at a temperature of 500° above the temperature of the engine room. Then, as raising one pound of the gases one degree takes .24 of a heat unit, raising it 500° would take .24 × 500, or 120 heat units. Raising 50 lbs. to that temperature would take 50 × 120, or 6,000 heat units. Thus he is sending 6,000 of his 14,000 available heat units, or 43 %, up the chimney, and he could not get more than about 50 % into the boiler, as about 7 % would be radiated and lost in other minor ways.

Twenty-five pounds of chimney gases per pound of coal is sufficient (practical trials with specially skillful firemen generally show less) and the average temperature of the chimney gases above the outside air in the 137 tests recorded by Mr. Geo. H. Barrus is not over 400°. Taking these values, only about 17 % of the heat would be carried up the chimney in this way.

An understanding of the operation of the furnace and boiler requires that we should know the following facts:

(1) The heat value of the fuel.
(2) The proportion of this heat used in making steam.
  (a) By incomplete combustion.
  (b) By hot gases passing up the chimney.
  (c) By radiation and dropping of fuel through the grate.
(3) The proportion of this heat lost.

The second and third added together should equal the first. Results may be checked in this way:

First:—In the answer to the first question we have tried to collect data that shall enable us to ascertain the approximate number of heat units (quantity of heat) that should be produced per pound of fuel burned. This has been collected from papers received from all over the country in reply to the first twelve questions. In said answer the first column contains the name of the coal, the second the number of heat units that will be produced by the complete combustion of one pound, the third column the number of pounds of water, from and at 212°, that would be evaporated, provided 60 % were used for this purpose; the fourth column the same as the third, except that 80 % instead of 60 % is here assumed; the fifth column gives the pounds of water, from and at 212°, that have been evaporated by one pound of some of the coals mentioned, in actual practical tests; the sixth column gives the per cent efficiency, corresponding to the actual evaporations named in column five.

Second:—The amount of water evaporated during a given time may be estimated as indicated in question No. 21 or in various other ways. This amount in pounds divided by the number of pounds of coal burned during the same time will give the evaporation per pound of coal. This multiplied by the number of heat units required to evaporate one pound will give the amount of heat utilized in making steam. Or the evaporation may be reduced to an equivalent evaporation from and at 212° by multiplying it by the proper number (factor of evaporation) contained in the following table abridged from "Kinealy on Engines and Boilers." This product multiplied by 966 will give the quantity of heat used in forming steam. Dividing the heat value of the coal by this last product will give the efficiency of the boiler and furnace.

Temperature of Feed Water.	Pressure of Steam by Gauge in lbs. per Square Inch. Factors of Evaporation.									
	O.P.	40P.	50P.	60P.	70P.	80P.	90P.	100P.	110P.	120P.
40	1.179	1.203	1.206	1.209	1.212	1.214	1.217	1.219	1.221	1.222
60	1.158	1.182	1.185	1.188	1.191	1.193	1.196	1.198	1.200	1.201
70	1.148	1.172	1.175	1.178	1.181	1.183	1.186	1.188	1.190	1.191
90	1.127	1.151	1.154	1.157	1.160	1.162	1.165	1.167	1.169	1.170
110	1.106	1.130	1.133	1.136	1.139	1.141	1.144	1.146	1.148	1.149
130	1.085	1.109	1.112	1.115	1.118	1.120	1.123	1.125	1.127	1.128
150	1.065	1.089	1.092	1.095	1.098	1.100	1.103	1.105	1.107	1.108
170	1.044	1.068	1.071	1.074	1.077	1.079	1.082	1.084	1.086	1.087
190	1.023	1.047	1.050	1.053	1.056	1.058	1.061	1.063	1.065	1.066

TEST OF BOILER AND FURNACE.

A complete test of a boiler and furnace would involve ascertaining the following facts:—

First. The quantity of heat generated by the combustion of the coal.
Second. The heat used in making steam.
Third. The proportion of the heat lost by—
  (a) Incomplete combustion.
  (b) Hot gases passing up the chimney.
  (c) Radiation and dropping of fuel through the grate.

The second divided by the first is the efficiency of the furnace and boiler.

The most considerable loss of heat is (usually) through the hot gases passing up the chimney. This may be easily estimated. It is also easy to estimate whether or not the loss from incomplete combustion is considerable.

If the fuel is not evenly distributed on the grate one may have too much air supplied to a part of the furnace and not enough to the remainder, so that excessive quantities of free oxygen (O_2) and of carbon monoxide (CO) in the chimney gases would indicate both an excessive amount of air and also incomplete combustion.

If the remaining sources of loss are very considerable it is owing to inexcusable mismanagement or imperfect apparatus. One author remarks that the remedy is to get a new fireman.

The following gives a tabulated result of an 1897 practical test:

Coal Used, Pocahontas (run of mine); Heat Value, 14,289.

	Heat units.	Per cent of total heat.
Useful evaporation	11374.044	79.6
Loss by chimney gases	1900.437	13.3
Unconsumed carbonic oxide	271.491	1.9
Loss by radiation, unconsumed hydrocarbons, evaporation of moisture in coal (2.3%) and unaccounted for	743.028	5.2
Total	14289	100

FIRST.

The Quantity of Heat Generated.

Mr. R. S. Hale, in his paper on "Fuel Gas Analysis in Boiler Tests," read before the American Society of Mechanical Engineers in 1897, remarks that it is not necessary to have an analysis of the coal, inasmuch as the data of the text books can be relied upon within very narrow limits. In answer to Q. 1, your committee has endeavored to supply reliable data; of course it is open to correction.

To find the quantity of heat that should have been generated in the furnace, one would look in the table, Ans. 1, for the kind of coal he was using, and opposite that he would find the number of heat units generated per pound of coal burnt. This multiplied by the number of pounds of coal burned in a given time would be the total heat that should have been produced during that time. The coal is usually weighed in the barrow upon platform scales.

SECOND.

The Proportion of Heat Used in Making Steam.

In the report of the Committee on Code, at this year's meeting of the A.S.M.E., occur these words:—

"The elaborate directions and multiplicity of details provided for in the foregoing code should not divert the mind from the fact that the principal elements to be ascertained in a boiler test are the weight of water evaporated and the weight of the fuel required to produce such evaporation."

The water fed to the boiler is best weighed in a separate tank, which is emptied into a tank from which the boiler draws its supply.

The amount may be approximately estimated as indicated in Ans. 21. It would perhaps pay to actually measure the water necessary to draw from the boiler to make the level drop from one mark to another on the water glass when the boiler was not in use. It might also be measured by a water-meter.

Having got the water evaporated, this amount would be divided by the number indicating the weight of coal used and the result reduced to an equivalent evaporation from and at 212° by multiplying by the

factor of evaporation taken from one of the numerous tables published.
The above last result would then be multiplied by 966, and the product divided by the heat value of the coal, to get the efficiency of the furnace and boiler, which should be from 60 % to 80 %.

ANALYSIS OF FLUE GASES.

As a check upon the above results, also a reliable indication of the performance of the furnace, we wish to know two things:—

First. How many pounds of gas are going up the chimney per pound of coal burned, together with its temperature?

Second. Whether or not a considerable amount of combustible gas is going up the chimney?

The first may be determined approximately by the rules given in Ans. 15.

A rough but practical estimate of the second may easily be made when we recollect that air is about 20 % oxygen by volume and 80 % nitrogen; that the nitrogen goes through the furnace unchanged; that as much of the oxygen as is properly used is changed to an equal volume of CO_2 (carbonic acid). Therefore if all the oxygen of the air is either unchanged or is changed to carbonic acid, the volume of the carbonic acid and oxygen taken together must still be 20 %, so that if we measure the volume of carbonic acid and oxygen, find what per

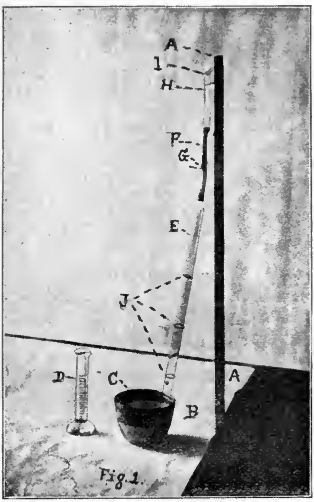


Fig. 1.

cent they are of the whole, taken together, subtract this result from 20, we shall have as a remainder a per cent which is roughly proportional to the combustible gases in the chimney. If this remainder is greater than 2 (two) it would generally indicate that insufficient air is being supplied to the furnace. In all ordinary cases the second is neglibly small.

For the volumetric analysis of the chimney gases the Orsat apparatus is generally recommended as accurate, convenient and reliable. Its cost is somewhere from $16 to $30. The form using pinch-cocks instead of glass-cocks is recommended by Prof. Gill as simpler, cheaper and more practical. Of this apparatus the Committee on Code of the A.S.M.E. says:—

"For the past year the writer has made extensive use of the Orsat apparatus in his boiler testing, and has found the work not only interesting, but exceedingly instructive and valuable. Its chief value lies in the guide which it affords in determining what kind of firing is most advantageous where the fuel is bituminous coal. That the instrument is reliable and useful for the purpose noted is quickly ascertained and without any very extended practice. When the thickening up of the fire is invariably attended with an increase in the percentage of carbonic oxide and a reduction in the percentage of oxygen, as the writer has found, he feels at once assured that the instrument is not a plaything or something that is influenced in unexplained ways by whim or caprice, but rather that it is an important adjunct to the engineer's outfit."

HOME-MADE ANALYZING TUBE.

The device described below, which has been constructed and used by your committee, is upon the same principle as the Orsat apparatus, but is, of course, not so elaborately constructed and graduated. This apparatus is illustrated in Figs. 1 and 2. Anyone can make it, and the apparatus itself ought to cost about 50 cents.

Fig. 1.—A is a stick held in a vertical position by a vise. B C is a small cup. D is a graduated measuring glass; it is immaterial into what units the glass is graduated, so that the unit is small. E is a glass tube ⅝″ or more in diameter and about 15″ long, drawn down in a gas flame at the ends, so that a small rubber (black preferred) tube, as F, may be slipped on and make air-tight joints. G is a pinch-cock by which the tube F may be closed air-tight. H is a funnel; in this case it is the part of the tube E that was separated from the rest when the ends were drawn down. I is a rubber band, which is placed around the stick A and funnel H to hold the apparatus in a vertical position. J are rubber bands upon the tube E. These may be moved to different positions on the tube, to serve as marks. If a graduated tube is used the glass D may be dispensed with.

METHOD OF USING.

The pinch-cock G is opened and the tube E filled with water, which is then allowed to run out slowly into the graduate and measurer. The measurement of this water determines the volumetric contents of the tube once for all. Suppose, for convenience, it is 100 cubic centimeters (though it may be anything; the larger, the more accurate will be the measurements).

It is generally thought best to lead a ¼″ or ⅜″ lead pipe from the "breaching" or a part of the flue near the up-take to a convenient place for filling the tube. We have used a small rubber hose. It is said that if rubber gets too hot it will generate gases that will effect the results.

To get the gases into the tube (see Fig. 3) one simply connects the tube C, in line with the pipe A, to the breeching X, and also to connect said tube to the inlet port of a hand air-pump B, and draws a dozen charges of the pump through the tube. This will clear out the air that was in the tube and replace it with flue gases. Perhaps it might be better to take a larger number of strokes of the pump.

A sort of ejector, like that shown in Fig. 4, may be used instead of a pump.

By the aid of a small jet of steam a steady stream of flue gases may be drawn through the tube.

A barrel, keg, or large can, filled with water, may be used for this purpose, as indicated in Fig. 5, in which C is the tube connected with the top of the barrel, and with the pipe A (Figs. 3 and 5). Letting the water run out of the bottom of the barrel draws the flue gases through the tube at the top. Care should be taken not to let the water get low enough so that air will be drawn back by the draft.

The tube E is connected, by means of rubber tubes upon its ends, with a pipe or tube leading to the chimney, and the flue gases are drawn through by means of an air pump or other convenient device until all the air is removed and the tube is full of chimney gases.

Having got the gases into the tube, the pinch-cock G is closed, the other end of the tube E is closed, say, by the finger (Fig. 2). The cup C is about two-thirds full of caustic potash solution. The finger

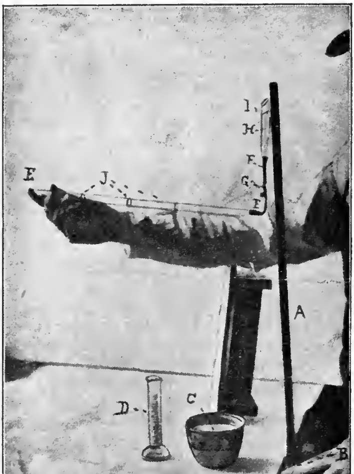


Fig. 2.

and end of the tube E are now put into the cup and the finger removed from the end of the tube while both are under the surface of the fluid. The apparatus is now in the position shown in Fig. 1, though the funnel H need not be on. The pinch-cock G is now opened for an instant until some of the fluid in the cup has run into the tube, and a rubber band, J, moved down to mark the surface of the fluid in the tube. The finger is again placed over the end of the tube (under the surface) and the tube turned up so that the fluid will run along the walls of the tube and expose a good deal of surface to the contained gas, as shown in Fig. 2. Upon placing the tube E back into the cup in the position of Fig. 1 it will be noticed that the fluid is drawn up into the tube.

Repeat the above operation three or four times at intervals of about a minute, or until the fluid no longer rises. Push another of the bands J down to mark the surface of the fluid in the tube.

The distance between the two rubber bands measures the volume of carbonic acid gas (CO_2) that was in the tube; this volume divided by the total volume of the tube above the first band is the per cent of carbonic acid gas in the flue gases.

Now, leaving everything in position, put the funnel H in the end of the rubber tube F, as shown. Then fill the glass graduate or any convenient vessel about two-thirds full of water and put into it all the snow-like pyrogallic acid that it will absorb. Fill the funnel with this pyrogallic acid solution and carefully open the pinch-cock G a very little, allowing a little of the contents of the funnel to run down. Be careful and not overdo this; enough to fill the tube ¼″ to ½″ is sufficient. On repeating the operation indicated by and described in reference to Fig. 2 it will be noticed that the fluid in the tube begins to turn a dark orange color and the level to rise. This indicates the absorption of oxygen.

When the level no longer rises, move another rubber band down to mark its position. The distance between the second and third rubber bands measures the free oxygen that was in the tube and has been absorbed; this volume divided by the volume of the tube above the first band is the per cent of free oxygen in the flue gases.

As long as the rubber bands, J1, J2, J3, are not moved, one may measure the volume of the tube between them as often as he pleases by drawing water up into the tube and allowing it to flow out into the graduate until it falls from one band to the other. If one wants very great accuracy he should calculate the effect of the column of fluid drawn up into the tube, and should be careful to let the tube drain long enough before measuring, and also consider the pressures of the water vapor. The temperature of the tube and contents must not vary during the operation.

The finger must never be removed from the end of the tube E, except when under the surface of the fluid in the cup C.

Unless one has particularly thin skin, or unless the operation is unnecessarily protracted, the caustic will do no harm. Running water, olive oil and muriatic acid will neutralize or remove the potash.

The writer has protected his finger by placing over it a thin rubber bag taken from the toy technically called a "cry-baby," sold at most of the shops for a nickel. Our brethren in New York and Chicago may be able to obtain something better for the purpose—something specially made to resist the action of corrosive fluids. [Rubber finger-stalls can be purchased from dealers in rubber goods.—Ed.]

COST OF APPARATUS.

Glass tube	$0.10
1 ft. black rubber hose	0.10
Glass graduate	0.25
Pinch-cock	0.10
1 lb. caustic potash	0.10
1 can pyrogallic acid	0.35
Total	$1.00

ESTIMATING THE WEIGHT OF THE CHIMNEY GASES.

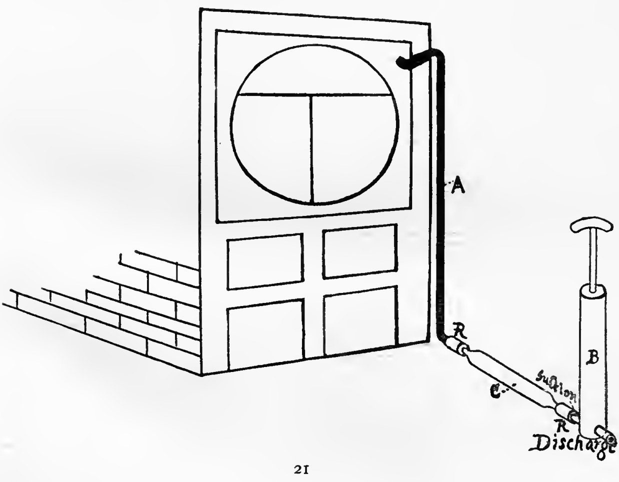
For this purpose it would only be necessary to ascertain the per cent by volume of the carbon dioxide. Ordinarily the weight of the gases per pound of coal would run about as follows for the corresponding per cents of CO_2.

Per cent carbon dioxide.	Weight of Flue Gases per lb. coal.
3.	61
4.	50
5.	40
6.	33.3
7.	28.6
8.	25
9.	22.2
10.	20
11.	18.2
12.	16.7
13.	15.4
14.	14.3
15.	13.3
16.	12.5

Under the conditions at each end of the column there would probably be considerable inflammable gases in the chimney gases. (See Ans. 16 and remarks under the heading "Analysis of flue gases.") That would have to be estimated as previously described. For the purpose of finding the volume of CO_2 only, the tube would not have to be manipulated, nor would it be necessary to put the hand nor any part of it into the alkali. A little of the potash solution would be put in the cup, the funnel would be filled with it, and a little let down occasionally by opening the pinch-cock so as to keep the walls of the tube covered with the solution. The correction for the weight of the column in the analyzing tube is made as above described in referring to the oil column except that the constant would be .0063.

AN ILLUSTRATIVE TEST.

Duration of test, 10 hours.
Kind of coal used, Pocahontas. Heat value, 14,290.
Weight of coal consumed, 6,507 lbs.
Water fed to boiler, 64,877 lbs.
Water per pound of coal, $64{,}877 \div 6{,}507 = 9.97$ lbs.



Equivalent evaporation from and at 212° $9.97 \times 1.19 = 11.80$ lbs.

Heat used in making steam per pound of coal used, $11.8 \times 966 =$ 11,398 B. T. U.

Efficiency of boiler and furnace, $11{,}398 \div 14{,}290 = .80$.

Gas analysis per cent by volume—carbonic acid 15.1, oxygen 4.

Leaving $20 - 19.1 = .9$ %, indicating a small amount of combustible gas in chimney.

Weight of chimney gases per pound of coal, $11 \times (15.1 + 4) \div 15.1 = 13.92$.

Temperature of flue gases above outside air, 529°.

Sensible heat in flue gases, $529 \times 13.92 \times .24 = 1{,}767$ heat units.

Per cent of heat in flue gases, $1{,}767 \div 14{,}290 = 12.3$.

	Heat Units.	Per Cent.
Steam making	11,398	80
Hot gases	1,767	12.3
Balance: radiation, unconsumed gases, dropping coal through grate, etc.	1,125	7.7
Total	14,290	100

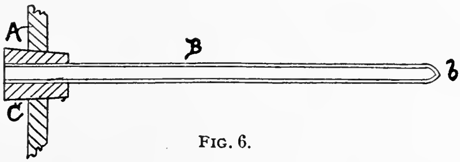


Fig. 6.

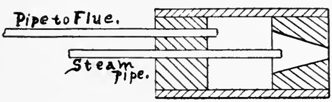


Fig. 4.

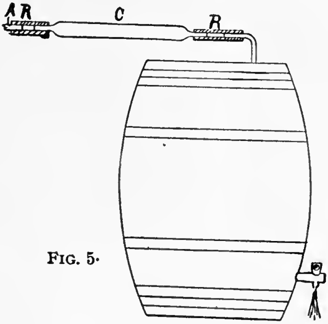


Fig. 5.

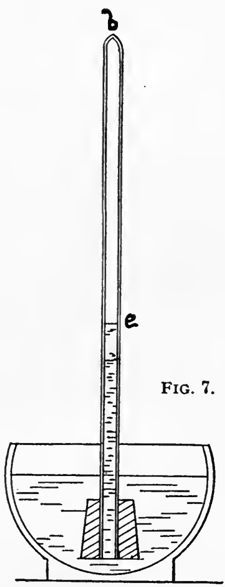


Fig. 7.

For practice in analyzing gases one may find the proportion of carbonic acid and oxygen in his breath. It is better to hold the breath as long as convenient before blowing it through a tube, and to blow through the tube enough times to be sure that all the air originally in the tube is expelled.

TEMPERATURE OF CHIMNEY GASES.

We have felt that the methods of ascertaining the temperature of chimney gases were not very available and practical for our purposes. Below will be found described a device for that purpose, which we believe accurate, simple and convenient.

The drawings are the work of one of the committee, and are intended simply to be illustrative, and no great accuracy nor proportion in sizes have been striven for.

We have experimented, successfully, we believe, with the following described apparatus:

In Fig. 6, A represents the front wall of the breeching; B is a glass tube, say ¼″ outside diameter, and as long as can conveniently be secured, drawn together at one end, b, in a gas flame; the other end, which is open, or slightly contracted, stuck through a cork or plug, C. The cork, C, is then forced into the hole in the breeching, so that the glass tube extends into the hot flue gases, as shown, and left there until it has the same temperature as the gases.

It is then taken out and placed with its open end under the surface of some high boiling point (flashing point) oil (we use engine oil) as shown in Fig. 7, and left there to cool. When it has cooled down to the temperature of the room, the oil will have risen up into the tube a certain distance, which is proportional to the amount the column of air in the tube has contracted in cooling, and therefore proportional to the change in the temperature of the tube. The column of air, b, e, Fig. 7, is now measured. Inasmuch as the volume of air is proportional to its absolute temperature and the volume of air in the tube, b, e, is at the temperature of the room and equal to the length of the tube at the temperature of the flue gases, therefore, b, e, is to the length of the tube as the temperature (absolute) of the room is to the absolute temperature of the flue gases.

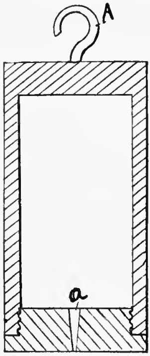
The tube we used was 15.5″ long. The temperature of the room was 90°; that is $460 + 90 = 550°$ absolute. The oil was drawn up 7″, leaving $15.5 - 7 = 8.5″$ as the length of the column, b, e, above the oil. Then 8.5 : 15.5 :: 550 : the absolute temperature of the flue gases. Therefore the absolute temperature of the flue gases was $550 \times 15.5 \div 8.5 = 1003$ or in ordinary measurement $1003 - 460 = 543°$. This would be $543 - 90 = 453°$ above the outside air.

The weight of the column of oil has a slight stretching out effect upon the air above it, because of its weight. To find how much should be added to the height of the column for this effect, one multiplies the height of the column of oil by the length of the tube above the oil and this product by .004; the result is the fraction of an inch that should be added to the height of the oil column.

In the above example the correction would be as follows: $7 \times 8.5 \times .004 = .238$. Therefore to the measured height of the oil column should be added about .24 of an inch.

One might use a metal tube, for instance a piece of gas pipe, with one end closed air tight and the other nearly closed, instead of the glass tube, if he prefers; but in this case he must have a measuring glass (or a pair of scales) to find the volume of the air in the tube originally, and the volume after contraction. For example: Suppose we had a tube of 2″ inside diameter, and 5″ long. We will fill it with water, then pour the water out and measure it, and find that it is 15.5 cu. ins. Then we put the tube into the breeching and let it get as hot

as the gases. Then we take it out and drop it into water, open end down. As it cools it will draw in some water. We then pour out the water it has drawn in and measure that, and find that it is 7 cu. ins. We would then have the same calculations as for the glass tube and the same figures, except for the correction for the weight of the column.



In Fig. 8 we have drawn our idea of this last form: A is a hook to hang it by in the flue or chimney. Of course the tube must be perfectly dry when placed in the flue and no steam in it. We do not think the evaporation of the water will effect the result.

When metal is used it would be well to have pretty thick walls so that the interior would not cool off before one could get it into the water. We would remark that the method of placing the tube in the chimney is a matter of personal choice and judgment.

COMPRESSED AIR.

The usual formula in the book is

$$PV^{1.4}=C$$

in which P is the pressure, V the volume, and C a constant which has to be calculated for each compressor.

This formula is somewhat difficult to use because it has a decimal fraction for the exponent of V. Moreover, it assumes that no heat is lost by the air which, owing chiefly to the relatively cool cylinder walls, but to some extent to the moisture in the air is never the case.

If, however, we assume an exponent of 1 1/3 or 4/3 we shall have a fundamental formula, that may be solved by the more familiar operations of squaring, cubing and extracting the square and cube roots. We shall also have a formula that will give results approximating closer to practice than the usual formula, because it allows for a small loss of heat. Absolute pressures and temperatures are always used.

The fundamental formula then is

$$(1)\quad PV^{\frac{4}{3}}=C$$

This may be put in the form,

$$(2)\quad PV\sqrt[3]{V}=C$$

which is a more convenient form to use. In words formula No. 2 says: "The pressure multiplied by the volume and this product by the cube root of the volume is always the same, that is, is equal to a constant."

From equation No. 1 the following formulas and rules may be derived:

FIRST.

To calculate the pressure, the volume being known:

Rule 1. Divide the constant by the volume multiplied by its own cube root.

That is
$$(3)\quad P=\frac{C}{V\sqrt[3]{V}}$$

We generally know the volume at the beginning of compression, and we also know that the pressure then is one atmosphere, say 14.7 lbs. If we wish to know the pressure at some other volume, we may use the following rule, as well as Rule 1.

Rule 2. Divide the greater volume by the lesser, and multiply this quotient by its own cube root. Multiply this last product by the pressure at the larger volume and we have the pressure required.

That is
$$(4)\quad P=P_1\,\frac{V}{V_1}\,\sqrt[3]{\frac{V}{V_1}}$$

For example, suppose we have a compressor that has a 12″ stroke and 10 sq. ins. area of piston, compressing to 74.7 lbs. (60 lbs. gage). The figure shows the indicator diagram. For convenience we measure the volume in inches of cylinder length.

We first find the constant, C, by formula 2. At the commencement of the stroke the pressure, P, is one atmosphere (14.7 lbs.) and the volume V is 12″ of cylinder length. Therefore, by formla 2

$$14.7 \times 12 \times \sqrt[3]{12} = C.$$
$$14.7 \times 12 \times 2.29 = C = 404.$$

Now suppose we want to know what the pressure is after the piston has traveled 6 inches. The volume remaining, or the distance the piston has to travel yet before reaching the end of its stroke, is six inches. Therefore by Rule 1 we divide the constant, 404, by the volume, 6″, multiplied by its own cube root.

$$404 \div 6 \times \sqrt[3]{6} = 404 \div (6 \times 1.817) = 404 \div 10.9 = 37 \text{ lbs.}$$

By Rule 2, we first divide the larger volume by the lesser, $12 \div 6 = 2$.

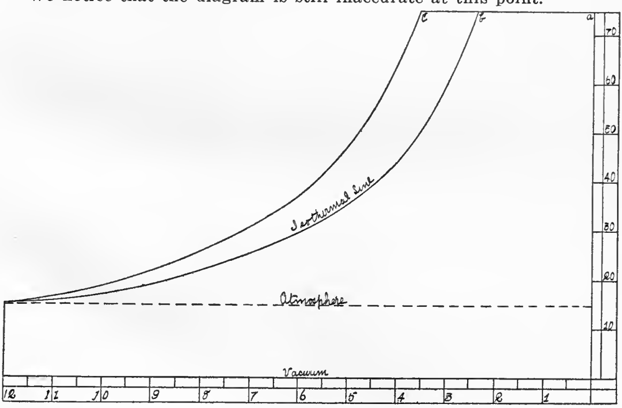
We then multiply this quotient by its own cube root,

$$2 \times \sqrt[3]{2} = 2 \times 1.26 = 2.52$$

We then multiply this product, 2.52, by the pressure at the larger volume, 14.7, thus $14.7 \times 2.52 = 37$ lbs.

Rule 2 is the simpler, and the form that will be generally used.

We notice that the diagram is still inaccurate at this point.



SECOND.

To find the volume, the pressure being known.

Rule 1. Divide the constant by the pressure, and multiply this quotient by its own square root, then extract the square root of the product, that is

$$(5)\quad V=\sqrt{\frac{C}{P}\sqrt{\frac{C}{P}}}$$

Rule 2. Divide the lesser pressure by the greater, and multiply the quotient by its own square root, extract the square root of this product, and multiply the larger volume by this square root

$$V_1=\sqrt{\frac{P}{P_1}\sqrt{\frac{P}{P_1}}}$$

Thus, if we want to know the volume at the end of compression in the above example, when we know the pressure is 74.7 lbs.

By Rule 1. We divide the constant by the pressure $404 \div 74.7 = 5.408$.

We then multiply this quotient (5.408) by its own square root, $5.408 \times \sqrt{5.408} = 5.408 \times 2.326 = 12.58$.

We then extract the square root of this product (12.58) $\sqrt{12.58} = 3.537$ or about 3.54 inches of cylinder length.

By Rule 2. We first divide the lesser pressure (14.7 lbs.) by the greater $14.7 \div 74.7 = .1968$.

We then multiply this quotient (.1968) by its own square root, $.1968 \times \sqrt{.1968} = .1968 \times .444 = .0874$ and extract the square root of this product ($\sqrt{.0874}$) $\sqrt{.0874} = .2956$.

We then multiply the greater volume, 12″, by this root (.2956), $12 \times .2956 = 3.54''$ inches of cylinder length. Which is the result required.

THIRD.

To Find the Net Work per Stroke of the Compressor.

Rule. First multiply the stroke (in feet) by the area of the piston (in square inches) and this product by 58, and call this result No. 1.

Second. Divide the greater by the less pressure, extract the fourth root (the square root of the square root) of this quotient, diminish it by unity (1) and call the remainder, result No. 2.

Third. Multiply result No. 1 by result No. 2 and the product is the work per stroke in foot pounds—(of work $= 59$ APV

$$V_1=V\sqrt{\frac{P}{P_1}\sqrt{\frac{P}{P_1}}}$$

Thus, if we wish to know the work per stroke in the above example, by Rule 1, we

First. Multiply the stroke in feet (1) by the area of the piston in square inches (10) and this result by 58, so that we have $1 \times 10 \times 58 = 590$. Result No. 1.

Second. We divide the greater (74.7) by the less pressure (14.7) and extract the fourth root of the quotient and diminish it by one

$$74.7 \div 14.7 = 5.082;\quad \sqrt[4]{5.082} = \sqrt{\sqrt{5.082}} = \sqrt{2.255} = 1.502$$

Diminishing this by one, $1.502 - 1 = .502$. Result No. 2.

Multiplying result No. 1 by result No. 2 we have $590 \times .502 = 296$ ft. lbs. per stroke.

The above rules, and formulas, are also applicable to the ammonia compressor.

FOURTH.

To Find the Compression Temperature.

Rule 1. Multiply the initial temperature (absolute) by the fourth root of the quotient obtained by dividing the greater by the less pressure. The result is the final temperature absolute.

$$(8)\quad T_1 = T\sqrt[4]{\frac{P_1}{P}} = T\sqrt{\sqrt{\frac{P_1}{P}}}$$

Thus in the example taken, assuming that the initial temperature is $60° = 460 + 60$ or 520 absolute, we have $T_1 = 520\sqrt[4]{5.082} = 520 \times 1.50 = 781$ absolute or $781 - 460 = 320°$ by the thermometer.

Compression temperature may also be found by drawing the isothermal line (steam expansion line) under the actual diagram.

The initial absolute temperature is to the final absolute temperature as the lengths of the horizontal lines drawn to the points of the curves where the temperature is to be measured. Thus referring to the figure or diagram:

$$T : T_1 :: ab : ac$$
$$ac = 3.54$$
$$ab = \frac{14.7}{74.7} \times 12 = 2.36$$
$$\therefore 2.36 : 3.54 :: 520 : T_1 \therefore T_1 = 780+$$

MISCELLANEOUS RULES.

The work, in foot pounds, per pound of air compressed may be obtained by multiplying the rise in temperature by the constant 213.

The weight of one cubic foot of air in pounds at any temperature and pressure may be found by multiplying its pressure by the constant 2.707 and dividing by its absolute temperature.

$$\text{Weight per cubic foot in lbs.} = \frac{2.707\,P}{T}$$

Under constant pressure the volume of air is proportional to its absolute temperature.

Under constant volume the pressure is proportional to the absolute temperature.

The specific heat of air is: Under constant volume, .1688; under constant pressure, .2377.

In two stage compression the intermediate pressure is equal to the square root of the initial and final pressure.

Question 1. (1897-8.) How much heat is produced by the complete combustion of —(a) one pound of anthracite coal, (b) one pound of bituminous coal—of average quality? Express answer in heat units and also in foot pounds. Name kind of coal

(See table on the following page)

Ans. 1. KIND OF COAL.	Heat Value	Theoretical Evaporation from and at 212°		Evaporation by recorded trial, 212°	Per cent. of heat accounted for by column 5.
		60%	80%		
PENNSYLVANIA ANTHRACITE.	12,000	7.45	9.93		
	to				
	14,900	9.245	12.32	10.07	70
	Average 13,916	8.63	11.51		
Beaver Meadow..........	14,098	8.74	11.52		
Peach M. Connellsville..............	13,551	8.4	11.21		
Lehigh..........................	13,800	8.56	11.42	11.17	78
Pittsburgh, Average.................	13,104	8.13	10.84		
Lackawanna..........................	14,500	9.	12.	11.13	74
Pennsylvania Buckwheat	12,200	7.57	10 09		
Honeybrook Lehigh..................				10.75	
Massachusetts Anthracite............	15,200	9.44	12.59		
BITUMINOUS, SEMI-BITUMINOUS, ETC.					
New River..........................	14,000	8.7	11.6		
Indiana Block.......................	14,000	8.7	11.6		
Kentucky Coking....................	14,400	8.94	11.93		
Pittsburgh Coking..................	14,400	8.94	11.93		
Youghiogheny	14,265	8.87	11.82		
Pocahontas, run of mine............	14,289*	8.87	11.82	11.53	78
Cumberland	13,614	8.46	11.27	8.74	62
Pennsylvania, semi-bituminous.	13,368	8.30	11.07		
Rock Spring, Wyoming.	13,000	8.07	10.76		
Bureau Co., Ill............	13,025	8.07	10.76		
Hocking, slack......................	11,083*	6.88	9.18	7.78	68
Jackson (nut and slack).....	12,139*	7.54	10.05	8.25	66
Bellmore Pea........................	12,240*	7.60	10.13	8.98	71
Big Muddy, Jackson Co., Ill.........	12,600	7.83	10.43		
Bituminous—1896 tests—heat value for ten mines scattered over Eastern and Southern Ohio (data furnished by Akron, Ohio, No. 28)........ ..	13,100	8.14	10.85		
Wood (assumed as .4 of coal used)...		3.48	4.68		
Lignite............................	10,300	6.40	8.50		
Crude Petroleum....................	19,200	11.93	15.90		
	*1897				

Q. 2. (1897-8.) How much heat will be produced by the incomplete combustion of one pound of coal of the kind assumed in Q. 1 (a)?

Ans. 2. Assuming 90% carbon, the heat produced will be $4,400 \times .90 = 3,960$.

Q. 3. (1897-8.) What are the products of combustion under the conditions of Q. 1 (a) and what are their approximate proportions?

Ans. 3. Carbonic acid gas (CO_2), also called carbon dioxide, a colorless gas consisting of 3/11 carbon and 8/11 oxygen by weight; formed by the union of the oxygen of the air with the carbon of the coal and having the same volume as the oxygen from which it was formed:—steam (H_2O) a colorless gas formed by the union of the oxygen of the air with the free hydrogen of the coal; consisting of one part by weight of hydrogen and eight parts of oxygen. The proportion of steam in the chimney gases is usually negligibly small.

Q. 4. (1897-8.) What are the products of combustion under the conditions of Q. 2, and what are their approximate proportions?

Ans. 4. Carbon monoxide (CO), a colorless gas consisting of 3/7 carbon and 4/7 oxygen by weight, formed by the union of the oxygen of the air with the carbon of the coal, and having twice the volume of the oxygen from which it was formed.

Q. 5. (1897-8.) What gas in large proportions in the chimney gases indicates that an insufficient quantity of air is being supplied to the whole or a part of the fuel?

Ans. 5. Carbon monoxide (CO).

Q. 6. (1897-8.) What gas in large proportions in the chimney gases indicates that too much air is being supplied to the furnace? What proportion of this gas is allowable in good practice, with natural draft?

Ans. 6. Oxygen (O_2). About 10% by volume.

Q. 7. (1897-8.) What would be the weight of chimney gases per pound of coal burnt, in good practice, with natural draft?

Ans. 7. About 25 lbs.

Q. 8. (1897-8.) What is the approximate specific heat of chimney gases? What do you mean by this answer?

Ans. 8. Twenty-four one-hundredths (.24). Each pound of the chimney gases raised 1° F. in temperature, absorbs twenty-four one-hundredths (.24) of a unit of heat.

Q. 9. (1897-8.) With the facilities of the average engine and boiler-room how can the temperature of the chimney gases be approximately determined?

Ans. 9. (1) By a thermometer, properly protected, placed in the chimney gases.

(2) By exposing a certain weight of iron to the gases until it acquires their temperature and then estimating the temperature of the iron [see answer to question 50 (1896-7).]

(3) By the melting point of alloys or metals exposed to the gases.

Q. 10. (1897-8.) What proportion of the heat produced by the burning of the coal should go to the formation of steam, in good practice and with a good boiler plant?

Ans. 10. From 60% to 80% (.60 to .80).

Q. 11. (1897-8.) How can the amount of heat produced by the furnace be approximately estimated and how can the proportion of said

heat that goes to the production of steam be approximately estimated?

Ans. 11. By multiplying the heat value of the coal used by the number of pounds of the same burned.

By multiplying the number of pounds of water evaporated by the heat required to evaporate one pound. The evaporation is usually reduced to an equivalent evaporation from and at 212°, and then multiplied by 966, the number of heat units required to change one pound of water at 212° to one pound of steam at the same temperature. —See answers to last year's questions.

Q. 12. (1897-8.) What would be the weight of the chimney gases per pound of coal burnt, in good practice, with a forced draft?

Ans. 12. About 19 lbs.

Q. 13. (1897-8.) What substance is used—

(a) For the absorption of carbonic acid gas (CO_2) from a mixture of gases;

(b) For the absorption of free oxygen (O) from a mixture of gáses?

Ans. 13. (a) A solution of caustic potash (commercial) in water from the hydrant. Proportions about 1 lb. of potash to 2 lbs. of water. Caustic soda may also be used.

(b) A solution of pyrogallic acid (pyrogallol) in water mixed with the above solution of caustic potash. Prof. Thurston used 5% pyrogallic acid.

Phosphorus may also be used.

Q. 14. (1897-8.) Describe a cheap and simple apparatus by which the proportions, by volume, of carbonic acid gas (CO_2) and of free oxygen (O) in the chimney gases may be determined. Describe method of use.

Ans. 14. Ga. No. 1 sends the following description:

"Fill a graduated test-tube with chimney gases. Close the mouth, invert the tube and put the mouth under water. Arrange the tube so that the level of the water inside and out is the same. Now introduce a piece of caustic potash fastened to the end of a wire; allow it to stand about 45 mins.; withdraw the potash. It will be found that the volume (of the gas) has diminished, which represents the per cent of CO_2 in gases. Rearrange the tube so the water level is the same inside and out; introduce a piece of phosphorus and allow to stand 24 hours. Withdraw the phosphorus. It will be found the volume has again diminished, which represents the per cent of oxygen."

The device which your committee has constructed and used is described and illustrated in a separate chapter.

Q. 15. (1897-8.) Assuming that a sufficient amount of air is supplied to the fuel and that the per cent by volume of carbonic acid (CO_2) and of free oxygen (O) in the chimney gases is known, how can the weight of the chimney gases per pound of coal be approximately determined?

Ans. 15. Add the per cent by volume of carbonic acid (CO_2) to the per cent by volume of oxygen (O_2); divide this result by the per cent by volume of carbonic acid, and multiply the quotient by the constant number ten and one-half (10.5).

2. Divide the constant number two hundred and ten (210) by the number indicating the per cent by volume of the carbonic acid (CO_2).

We remark that the above rules are for finding the weight of gases per pound of coal, and not per pound of carbon or combustible in the coal. It is therefore necessary to assume an arbitrary constant which will give the average value. For the combustible the above constants would be about 12 and 240; for a particularly good coal they would be about 11 and 220.

Q. 16. (1897-8.) Knowing the per cent by volume of carbonic acid gas (CO_2) and of free oxygen (O) in the chimney gases, how can the per cent by volume of carbon monoxide (CO) be calculated, neglecting water vapor and hydrocarbons?

Ans. 16. Add the per cent by volume of carbonic acid (CO_2) and of oxygen (O_2), multiply the result of 5, subtract the product from 100 and divide the remainder by 3.

Q. 17. (1897-8.) If coal, having a heat value of 14,000 units per lb. is used, the feed-water is at 100 degrees, the pressure is 70 lbs. gage, it is found that 30 lbs. of water is evaporated by 4 lbs. of coal burned:—What per cent of the heat produced by the combustion of the fuel is used in making steam?

Ans. 17. The heat produced by the coal should be $14{,}000 \times 4 = 56{,}000$. The factor of evaporation for feed-water at 100° and pressure 70 lbs. is 1.149. Therefore the equivalent evaporation from and at 212° is 30×1.149, which is 34.47, $34.47 \times 966 = 33{,}298$, which is the number of heat units used in making steam. Therefore the per cent of the heat used in making steam is $33{,}298 \div 56{,}000 = 59.46$.

Q. 18. (1897-8.) If under the conditions of Q. 17 it were found that the temperature of the chimney gases was 450° F. above the air in the boiler room, and that 40 lbs. of air was being supplied per pound of coal burned, what per cent of the heat produced by the combustion of the coal would be going out of the chimney with the gases?

Ans. 18. If 40 lbs. of air was supplied per pound of coal the weight of the chimney gases would be about 41 lbs. per pound of coal; the heat carried up the chimney by this would be about $41 \times 450 \times .24 = 4{,}428$, and the per cent is $4{,}428 \div 14{,}000 = 31.6$ (about).

Q. 19. (1897-8.) What is the relative approximate permeability to heat of clean boiler plate, ⅜″ thick, and the same plate covered with ⅛″ of hard sulphate scale?

Ans. 19. From two to one (2 to 1), to two to one and a half (2 to 1.5).

Q. 20. (1897-8.) How is the condition of the boiler indicated by a change in the temperature of the chimney gases, and why?

Ans. 20. A rise in the temperature of the chimney gases would indicate a dirty boiler, as scale on the inside or soot on the outside would reduce the conductivity of the metal, and a greater quantity of heat would pass out with the gases.

Q. 21. (1897-8.) A horizontal boiler is 18 ft. long, 72″ diameter, pressure 70 lbs. gage. The lower end of a twelve inch water glass is 48″ from the lowest point of the boiler. At 9 a. m. the water is 4″

below the upper end of the glass, the feed is then stopped. At 9:45 a. m. the water is 5″ from the lower end of the glass. How many pounds of steam is the boiler supplying per hour?

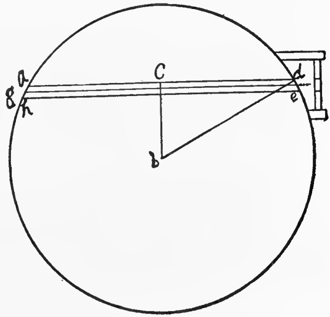


FIG. 1

Ans. 21. The water has fallen 3″ or one-quarter of a foot. The average width of the surface while falling multiplied by the length of the boiler (18 ft.) and by the distance through which the level has fallen, gives the volume of the water used. This expressed in cubic feet and multiplied by 56.8, the weight of water at the temperature corresponding to 70 lbs. gage (316°), will give the weight of water evaporated in the given time—three-quarters of an hour. This result divided by .75 will give the weight of water per hour that the boiler is evaporating.

To find the average width of the surface one might take the width at the higher and at the lower levels, add the two together and divide by 2.

The width of the surface (a d Fig. 1) at the higher level may be found in subtracting the square of its height (b c) above the center of the boiler from the square of the radius (36″), extracting the square root of the result and multiplying by 2.

Thus:—Radius equals 36″, square of radius = 1296. Height from center of boiler 20″, square of height 400; 1296 — 400 = 896. The square root of 896 is 29.933, and twice this is 59.866, which is the width of the surface at the higher level. The width of the surface at the lower level may be found in the same way to be 63.46; 59.866 + 63.46 ÷ 2 = 61.66″, or about 5.14 ft., as the average width.

It would perhaps be better to draw a diagram like Fig. 1 to as large a scale as practicable, say one-half, then draw a line f g half-way between the lines a d and h e, which indicate the higher and lower levels. Then carefully measure the line g f. With the scale suggested, the line will be found to be about 30 13/16 long, which, multiplied by 2, because of the reduced scale, will give about 61.63″.

This illustrates the simplicity and practical accuracy of graphical methods of calculation.

Taking the average width as 5.14 ft., the length as 18 ft. and depth as .25 ft., the volume of the water evaporated would be 5.14 × 18 × .25 = 23.13 cubic feet, and its weight is 23.13 × 56.8 = about 1313 lbs. This multiplied by 4 and divided by 3 gives about 1751 lbs. of water per hour.

Q. 25. (1897-8.) The gage pressure being 120 pounds, the feed water 110° and the engine using 15 lbs. of steam per horse-power-hour, what part of the heat that went to the making of steam is transformed into useful work by the engine? What per cent is this of the heat generated in the furnace, the efficiency of the furnace and boiler being .70?

Ans. 25. (a) The total heat in steam above 32° due to 120 lbs. gage pressure is 1188 H.U. and the heat already in the water is 110 — 32 = 78 H.U. Then, the heat required to change 1 lb. water at 110° into steam at 120 lbs. gage pressure is 1188 — 78 = 1110 H.U. The engine in question uses 15 lbs. of steam per horse-power, which is equal to 15 × 1110 = 16,650 H.U. As 1,980,000 is equal to one horse-power per hour, and 1 H.U. equals 778 ft. lbs. of work.

$$\frac{1{,}980{,}000}{778} = 2545.$$

the H.U. changed into work per HP. per hour. Then the per cent of heat that went to make steam and was changed into work by the engine is

$$\frac{2545}{16650} \times 100 = 15.22\ \%.$$

(b) If the furnace and boiler has an efficiency of 70 % and the boiler uses 16,650 H.U. for 15 lbs. of steam, the heat of the furnace would have to produce for each 15 lbs. of steam

$$\frac{16650}{.70} = 23785.7 \text{ H.U.}$$

and the per cent of this heat that went to do useful work is

$$\frac{2545}{23785.7} \times 100 = 10.7.$$

Q. 42. (1897-8.) Give three ways of calculating the area of the end of the boiler above the tubes, which is supported by braces?

Ans. 42. Taking the segment as less than a half circle and of the size that it is usually necessary to brace on the end of a boiler:

FIRST METHOD.

Take one-half the area of the entire circle of which the segment is a part. Call this result No. 1. Multiply the diameter of said circle by the height of the base of the segment above the center of the circle. Call this result No. 2. Subtract result No. 2 from result No. 1 and the remainder is the area of the segment very nearly. The result is a little too small.

SECOND METHOD.

Subtract twice the distance from the base of the segment to the center of the circle from half the circumference of the circle and multiply this result by one-half the radius of the circle. Call this result No. 1. Multiply the radius of the circle by the height of the base of the segment above the center. Call this result No. 2. Subtract result No. 2 from result No. 1 and the remainder is the area of the segment very nearly. The result is a little too small.

THIRD METHOD.

Draw the segment to as large a scale as convenient and measure its area by the planimeter.

Inasmuch as two or more methods of solving a problem are sometimes useful as a check upon each other, and as some will prefer to use

one way and some another, the graphical methods of solving the segment problem might be entertaining and useful. We believe that these methods as given are sufficiently accurate for practical purposes. The second method is quite accurate if one-half the base of the segment is taken instead of the radius of the circle, in calculating the triangular area.

AN EXAMPLE.

The circle is 53″ in diameter. The height of the base of the segment above the center of the circle is 7.5″. (See Fig. 6.)

First Method:—The area of the circle, a b c f, 53″ diameter, is 2206.18 sq. ins. The area of the semi-circle, g b h, is one-half of 2206.18 or 1103.09 sq. ins. Which is result No. 1.

If you multiply the diameter g h, equal 53″, by the height e d, equal 7.5″, you get 397.5 sq. ins., which is a little greater than the area g a c h. If you take the area g a c h from the area g a b c h, you have left the area of the segment, a b c e. Therefore 1103.09 — 397.5 = 705.59 sq. ins., the approximate area of the segment.

Second Method:—If you subtract twice the height e d, from the semi-circumference g a b c h, you have approximately the length of the line a b c. If you multiply the line a b c by one-half the radius, a d, you have the area d a b c. If you multiply the radius by the height e d, you have approximately (a little large) the area of the triangle d a c e. If you take the area d a c e from the area d a b c, you have the area a b c e remaining, which is the area of the segment.

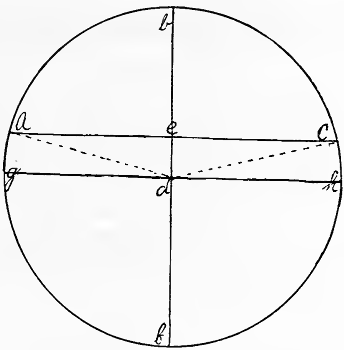


Fig. 6

Referring again to Fig. 6:—The circumference of a circle having a diameter of 53″ is 166.5″. One-half this (the line g b h), is 83.25″. If from this you subtract twice the height d e, that is twice 7.5″ or 15″, you have 83.25 — 15 = 68.25″, which is approximately the length of the line a b c. If you multiply this by one-half the radius, you have 68.25 × 13.25 = 904.31 sq. ins., or the area d a b c. This is result No. 1.

If you multiply the height d e, by the radius of the circle, you have 7.5 × 26.5 = 198.75 sq. ins., which is nearly the area of the triangle a c d. A little large. This is result No. 2.

Subtracting result No. 2 from result No. 1 you have 904.31 — 198.75 = 705.56 sq. ins., for the area of the segment, which is a little small because the area of the triangle was a little large.

By the formula of the answer to last year's Q. No. 15, and by accurately figuring by the second method, the area will be found to be about 710 sq. ins.

Q. 43. (1897-8.) If a boiler brace is attached to the shell 4 ft. from the end of the boiler and to the end of the boiler 2 ft. from the shell, what would be the strain upon the brace as compared to an end-to-end brace supporting the same area?

Ans. 43. The strain upon the brace attached to the shell would be to the strain upon the end-to-end brace as the length of the first mentioned brace is to the distance of its point of attachment to the shell from the end of the boiler. In this instance 1.118.

Q. 48. (1897-8.) What are the different ways in which a riveted joint may give way?

Ans. 48. The plate may tear across along the line of least cross-section a, b, Fig. 7, (a).

2. The plate and rivet may be crushed, as shown in (b).
3. The plate may break across in front of the rivet, (c).
4. The rivet may shear across, (d).

Q. 49. (1897-8.) What is the general rule for selecting the diameter of rivets for a given thickness of boiler plate? What should be considered in determining the diameter of rivets?

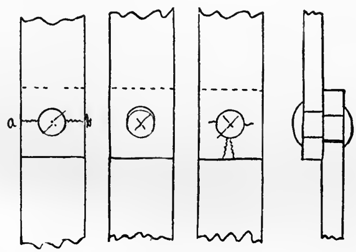
Ans. 49. If the rivet holes are to be punched, the punch should have a diameter as great as the thickness of the plate, otherwise it is liable to be broken. Drilled holes are not made less in diameter than the thickness of the plate.

As the shearing strength of the rivet increases with the square of its diameter, and the crushing strength of the plate in front of the rivet increases only as the first power of the diameter, there will evidently soon come a time, as the rivet is increased in diameter, when the shearing strength of the rivet is greater than the crushing strength of the plate. A correctly designed joint should be equally strong in all its parts.

The rivets should be close enough together to hold the joint tight.

The rule given by Unwin is to make the diameter of the rivet 1.2 times the square root of the thickness of the plate—

$$d = 1.2 \sqrt{t}.$$



(a) (b) (c) (d)

Q. 50. (1897-8.) What effect does the length of a tube have on its collapsing strength?

Ans. 50. No. 12 of Boston, Mass., says:

"The longer the tube the lower will be its collapsing pressure. First, because a short tube will retain its circular form better than a long one owing to the tendency of the long tube to sag in the middle and

get out of shape and, again, the short tube has the advantage of the support of the heads to which it is attached. This support would also be given to the long tubes, but would not have the same effect at the middle of its length. Large flues, like those in marine boilers are strengthened by rings placed at regular intervals to hold the flue in shape. Another method is to make the flue of short lengths, joining the ends by riveting them to the rings. Another method is to make the flues corrugated. All of which goes to show that a short tube will stand a greater external pressure than a long one."

While the above seems about right to the committee, still it is said that for the purpose of calculating the thickness of the tube, the length beyond ten or twelve diameters may be neglected.

Q. 58. (1897-8.) If a boiler weighing, with its contained water, 10 tons, is supported by four symmetrically-placed round wrought iron rods, what should be the diameter of the rods?

Ans. 58. Each rod would have to support ¼ of the entire weight (10 tons), or 5000 lbs. Allowing 10000 lbs. as the safe working strain per square inch of cross-section each rod would require .5 of a square inch cross-section, which corresponds to a diameter of .8″.

To allow for the change of temperature and corrosive action to which the rods would be subjected, the rods would probably best be made 1″ or 1.125″ in diameter.

BOOKS REFERRED TO BY THE COMMITTEE OF 1897-8.

Gas and Fuel Analysis, for Engineers—Gill—published by John Wiley & Son.

Hempel's Gas Analysis—translated by Dennis—published by Macmillan & Co.

Boiler Tests—by Geo. H. Barrus—published by the author.

We would refer any one wishing to read up on the subject of the graphical representation of the forces of inertia in steam engines, to Holmes on "The Steam Engine," published in Appleton's "Text Books of Science" series. The subject is treated, however, in nearly all books on mechanics or the steam engine.

Upon the subject of lubricating oils. Thurston's work on "Lost Work in Machinery," etc., published by Wiley, or G. H. Hurst on "Lubricating Oils."

Gill on Oil Testing.

The following are standard and reliable works on the strength of materials:

Strains in Framed Structures, by Bindon B. Stoney.
Unwin's Machine Design.
Rauleaux's Constructor, translated by Supplee.
Weisbach's Mechanics Vol. 1, translated by Cox.

We think the works of Silvanus P. Thompson, "Elements of Electricity and Magnetism," "Electromagnets and Electromagnetic Machinery," and "Dynamo-Electric Machinery," are about as good as any on this subject.

A book entitled "Mechanical Draft," published as an advertisement, your committee regard the first hundred or hundred and fifty pages as the best work on the subject of combustion they have met.

The Educational Committee.

INTRODUCTION TO QUESTIONS 83 TO 112 (1898-9).

The final list herewith has been prepared with care. The questions are intended to be quite general and will require but little mathematical discussion if handled in that manner. "Off hand" estimating is a fac-

ulty of as much value as the more refined calculations which the same points are also susceptible of—neither is superfluous and both should be cultivated energetically.

Q. 83. (1898-9.) At what standard of temperature is the evaporation of steam boilers usually expressed, irrespective of the actual temperature of the feed water or the pressure at which the steam is taken off?

Ans. 83. For comparison it is usual to reduce the results of boiler tests to a known standard. This standard is technically known as the "equivalent evaporation from and at 212°." This means that the evaporation is considered to have taken place at mean atmospheric pressure and at a temperature due to that pressure and the feed water also being assumed as supplied at that temperature.

One pound of water evaporated "from and at 212°" is equivalent to 965.7 B. T. units.

Q. 84. (1898-9.) Explain the difference between a pound of coal and a similar weight of "combustible."

Ans. 84. The distinction between equal weights of coal and combustible is as follows: A pound of coal always contains a "per cent" of moisture and non-combustible matter in the form of ash and clinker. After deducting this the remainder is useful for combustion. A pound of combustible consists of such substances as can be completely burned or consumed—leaving no refuse.

Q. 85. (1898-9.) How many pounds of coal burned each hour, per square foot of grate, is considered a fair and economical rate of combustion?

Ans. 85. When economy is a consideration the rate of combustion must evidently not exceed the absorbing capacity of the boiler. With grate and heating surfaces properly proportioned the best economy is claimed for a rapid combustion of the fuel.

From 15 to 20 lbs. of coal per hour burned on each square foot of grate is considered good practice for factory boilers, the latter rate requires an exceptionally strong draft and is well up to the limit unless mechanical means are resorted to for hastening the consumption of the fuel.

Q. 86. (1898-9.) What is a good "evaporation" per pound of coal for boilers of horizontal tubular type, under fair average conditions?

Ans. 86. The evaporation from boilers of the horizontal tubular type, under fair conditions, may range from 7½ to 9½ lbs. The lower figure is probably more common and the latter may be slightly exceeded. Much depends upon the kind of coal and the methods and manner in which the plant is conducted.

Q. 87. (1898-9.) What "check" or test is necessary to obviate deceptive results or magnify the evaporative efficiency of a steam boiler?

Ans. 87. A calorimeter test should always be made where accurate results are wanted to determine the quality of steam and per cent of primage. This percentage must be deducted from the apparent evaporation to arrive at a true result; that is, actual evaporation.

Q. 88. (1898-9.) As an example, name a rate of evaporation, per pound of combustible, that you would regard with suspicion.

Ans. 88. Efficiency of the furnace and the boiler is determined by a comparison of the heat units accounted for in the steam produced and the theoretical value of the fuel consumed. Combustion is always more

or less incomplete; fuel is lost by dropping through the grate; heat is carried away by the hot gases and lost by radiation, hence when the difference between the theoretical and realized values seems too small to cover these losses, there is good cause for caution in accepting the accuracy of figures which represent an abnormal rate of evaporation.

Naming 12 lbs. of water evaporated from and at 212° Fahr. as a rate open to suspicion we may reckon $966 \times 12 = 11592$ B.T.U. accounted for in steam. This is about 82% of 14000, the latter figure being the assumed value of the combustible. Experience shows that 18% will not cover the losses attending common practice; 40% is not an unusual loss and less than 20% is seldom, if ever, attained.

Q. 89. (1898-9.) For a safe working pressure of 100 lbs. gage pressure give the maximum diameter and also the greatest length desirable for horizontal tubular boilers.

Ans. 89. A well-proportioned horizontal externally fired tubular boiler working under 100 lbs. pressure should not be larger than 72″ diameter and 18 feet long.

The Hartford Steam Boiler Inspection and Insurance Company, at the request of this committee, kindly furnished the following on this question:

"This company does not approve of the employment of plate thicker than ½″ in the construction of externally fired boilers. Keeping within this limit of thickness and assuming the tensile strength of plate at 60000 and that all the usual requirements as to ductility and elongation are complied with. The diameters for a plate thickness of 15/32″ are as follows, the sizes varying with the efficiency of the joint used in the longitudinal seams:

Safe working pressure 100 lbs. Factor of safety—five.

(a) For double-riveted lap-joint having 70% efficiency, diameter 78″.
Proof:

$$\frac{60000 \times 0.46875 \times .70}{(\text{Radius})\ 39 \times 5} = \frac{19687.5}{195} = 101 \text{ lbs.}$$

(b) For triple-riveted lap-joint having 75% efficiency the diameter may be increased to 84 inches.
Proof:

$$\frac{60000 \times 0.46875 \times 75}{(\text{Radius})\ 42 \times 5} = \frac{21094}{210} = 100 \text{ lbs.}$$

(c) For triple-riveted butt joint with double straps and securing an efficiency of 86%, the corresponding diameter is 96 inches.
Proof:

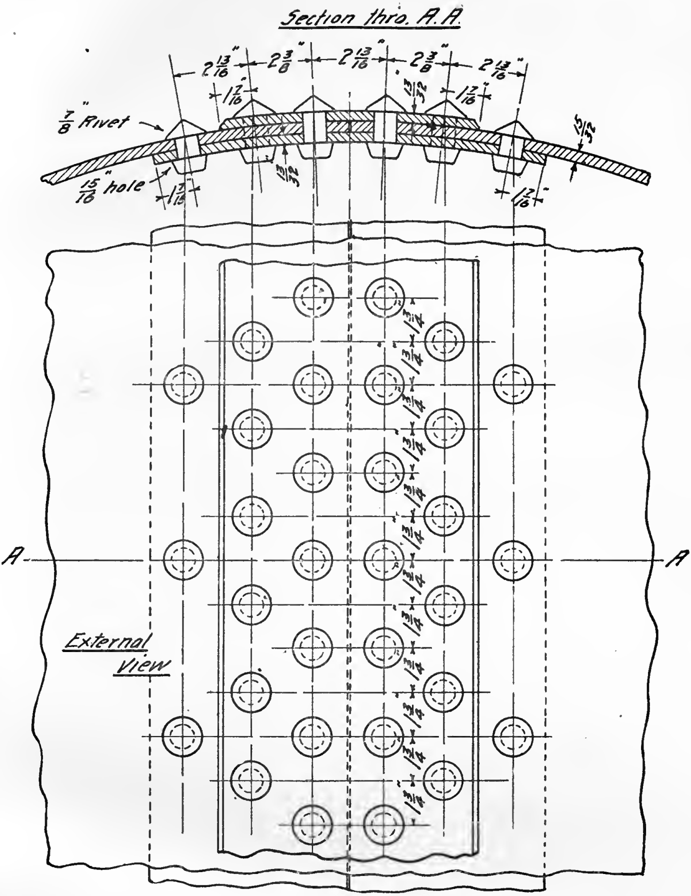
$$\frac{60000 \times 0.46875 \times .86}{(\text{Radius})\ 48 \times 5} = \frac{24187.5}{240} = 100\tfrac{3}{4} \text{ lbs.}$$

Length of boiler having 3½″ or 4″ tubes should not exceed 18 feet. The proper length should be determined by the ratio of heating surface to grate area, and the area of tube opening to grate area. By our tests we have found the former should be about 46 to 1 and the latter when bituminous coal is used should have an area of from 1/6 to 1/7 of the grate surface.

All specifications issued by this company for this type of boiler have a factor of safety of five and is considered none too much.

The efficiency of the three joints mentioned, that is, 70, 75 and 86% of the solid plate when properly proportioned, can be realized. The latter form of joint is illustrated herewith."

Q. 90. (1898-9.) What is generally claimed for all boilers of the water-tube class? Define also the advantages and the disadvantages



Triple Riveted Butt Joint for 15/32 inch Plates

Efficiency 86%

Answer No. 89.

attributed to those constructed with straight, and with curved, water tubes?

Ans. 90. It is generally claimed for water-tube boilers:

(a) They are safe from destructive explosion at extremely high pressures.

(b) Can be forced far beyond their normal capacity with impunity.

(c) Occupy small space and weigh less per unit of power developed.

(d) Economy in the use of fuel.

(e) Are easily cared for, etc., etc.

Some of these claims, in some instances at least, have no foundation in fact.

The advantages of straight water tubes are, that they can be easily inspected and cleaned and a standard tube of the required length can be used for renewals. One alleged disadvantage is, that owing to their straight form they are liable, on account of expansion and contraction, to severely strain the headers they are expanded into. This, however, is thought to be more imaginary than real and the thousands of boilers of this type in successful daily use bear out this assumption.

The advantages claimed for a "curved" tube are, that neither the tube or its connections are injured by unequal expansion or contraction. Such tubes are, however, difficult to properly inspect and clean; they are hard to repair, and this is especially true of boilers containing different lengths and bends. There are unusual conditions where boilers with bent tubes are a necessity and are also desirable, but we do not believe that these conditions obtain in stationary practice. There are many of this type and most of them are a delusion and a snare in bad water.

Q. 91. (1898-9.) How many square feet of heating surface per horse-power is a customary allowance in horizontal tubular boilers? Give also a similar approximation for water-tube boilers of average efficiency?

Ans. 91. Fifteen square feet of heating surface per horse-power is a common allowance for externally fired boilers of the horizontal tubular type, and ordinarily this is sufficient when such boilers are used to supply simple throttling engines. For "Corliss" class of engines the allowance is more usually restricted to 12 square feet.

Water tube boilers are rated at 7 to 11 sq. feet. All such ratings should be regarded only as an approximation; a better method is to take into consideration the various conditions which apply to any particular case.

Q. 92. (1898-9.) Give an average ratio of grate and heating surfaces in horizontal tubular boilers which give good results and note such conditions as may prompt a change in the proportions given?

Ans. 92. For horizontal tubular boilers a ratio of heating surface approaching 35 to 46 to one square foot of grate is usually productive of good results.

High furnace temperature and rapid combustion yield economy; the rate of combustion is always determined by the "draft" and the more rapid the consumption of fuel on the grate, the greater should be the extent of the heating surface. Draft in turn, however, is ordinarily dependent on the temperature of the escaping gases, hence the increased ratio referred to must be limited, of course, to a point where the draft remains equal to the requirements of the furnace.

Q. 93. (1898-9.) For a plant requiring 200 HP, working steam pressure 100 lbs., and which is to be operated reasonably free from interruption, due to cleaning and repairs, give general dimensions and the number of horizontal tubular boilers you would install. State also

how such should be set, i. e., singly or in pairs, to fill the requirements at a minimum cost.

Ans. 93. (a) Assuming that the 200 HP plant referred to in the question is to be used for manufacturing purposes and is not to run on Sundays or holidays the boilers required would be two 66″ dia. 16 ft. horizontal tubular type—54-4″—tubes. To be of standard design and material, first-class workmanship and capable of safely carrying 100 lbs. pressure per square inch. Boilers to be set over separate furnaces and properly connected so they could be run independently if necessary.

(b) Another answer provides a third boiler—which would be necessary, of course, for a plant designed for continuous operation. This answer is expressed as follows:

We would recommend three boilers of the horizontal tubular type set singly; that is, with partition walls between adjacent boilers—each to be provided with separate grate, steam and water connections, enabling any one of the three to be operated independently. Each smoke connection to stack to have damper and each boiler to be provided with an independent gage in addition to the steam gage connected to the main header.

Each boiler to develop 100 HP; that is, must be capable of evaporating 3450 lbs. of water from and at 212° per hour. Allowing 12 square feet of heating surface per HP would therefore require 1200 square feet in each boiler.

A boiler 66″ diameter—18 feet long, fitted with 54-4″ tubes fulfills this requirement.

Q. 94. (1898-9.) Describe briefly, without detail, the method of supporting horizontal tubular boilers which you regard with favor?

Ans. 94. Boilers are best supported by being hung up on steel framing in a way that the brick work is relieved from all weight. This makes it much easier on their "settings" and greatly facilitates work in case of needed repairs. Properly designed, such an arrangement allows freedom for expansion, without cracking brickwork.

Q. 95. (1898-9.) Which is preferable in horizontal tubular boilers, the dome, steam-drum, or dry-pipe?

Ans. 95. The dome or steam drums are expensive adjuncts to horizontal tubular boilers and are useless on boilers which are well designed and proportioned with a view of dispensing with either. A properly designed "dry-pipe" is an equivalent, answering every requirement when all other things are equal.

Q. 96. (1898-9.) Do you consider the advantages claimed for mud-drums sufficient to outweigh such objections as their use entails?

Ans. 96. The trend of modern "ways" is to dispense with mud drums on horizontal tubular boilers. They deteriorate rapidly and are therefore considered costly and not ordinarily necessary, although in Mississippi River practice and other places where only muddy unfiltered water is available, the mud-drum is still regarded with some favor.

Q. 97. (1898-9.) What style of cock or valve is best adapted for lower "blow-off" of boilers?

Ans. 97. For "blow-off" use a valve with passages calculated to pass freely all particles likely to get into the blow-off pipe. A globe valve is out of place, because it does not meet the above requirement. Valves "handle" easier than plug cocks and are less liable to "jar" and thereby injure the pipe and connections. Asbestos-packed cocks are claimed to be more satisfactory than the ordinary kind.

Q. 98. (1898-9.) Give the proper position for a "surface blow"; state how its details should be arranged and explain the purpose it serves.

Ans. 98. A "surface blow-off," as applied to a horizontal tubular boiler, consists of a flat funnel-shaped appendage inside of the shell, preferably located near the rear end with the wide mouth of the funnel placed at the water line and directed toward the front of the boiler. This should be connected to a 1¼" pipe leading out of the back head of boiler and a valve should be located in an accessible position so it can be used frequently while the boiler is in operation.

The purpose served is the removal of the sludge and scum that is always more or less upon the surface of the water when boilers are being worked. When properly installed and attended to, a surface blow-off is very helpful and greatly relieves certain conditions which tend to cause "foaming."

Q. 99. (1898-9.) What form of connection do you approve for a water-column and how should gage-cocks and water-glass be placed with reference to the tubes in horizontal tubular boilers?

Ans. 99. A water-column should be connected to boiler with pipe not smaller than 1¼". (The Hartford Steam Boiler Inspection and Insurance Company advocates seamless brass tubing, iron pipe size and brass ground-joint unions.) The fittings for lower or water end should be crosses or tees with brass plugs for ready removal in cleaning and inspection.

Valves should not be put on the pipes between the boiler and columns, as these are a possible source of danger. By making the "blow-off" pipe to column ¾" or 1" there is no need of any valves at this dangerous point.

The lower gage cock and bottom of water glass should be placed on a line 3" above top row of tubes; that is, water should appear in the glass when tubes are covered to a depth of 3".

Q. 100. (1898-9.) Give size and specify the number and style of safety valves necessary for the boilers referred to in Q. 93—pop or lever pattern?

Ans. 100. Good "pop" safety valves of standard make are preferred; each boiler to have its own valve; every valve to be in direct communication with the boiler which it serves and placed with no intervening means of shutting off same.

The grate area to be provided for either of the boilers described in Ans. 93 will hardly be less than 30, or more than 38, square feet. Figuring on the maximum grate area and allowing one square inch of valve area for three square feet of grate we should provide a valve having $38 \div 3 = 12\ 2/3$ square inches, which is nominally the area corresponding to a 4" diameter.

(Ed. Com.)—The above is the U. S. government allowance and is only one of the many rules on this subject. There are other modes, more logical, perhaps; see Kent's Pocket Book, 1898, page 723.

While it is not a common practice to provide two smaller valves instead of one larger one, yet there seems much in this idea that is commendable, especially when the valves are set to blow off at slightly different pressures.

Q. 101. (1898-9.) What are fusible plugs made of and where should same be placed in horizontal tubular boilers?

Ans. 101. Fusible plugs are usually ¾ or 1" pipe size with a taper hole through them which is filled with Banca tin. The tin is calculated

to fuse when not covered with water, but certainty of action depends on proper exposure; that is, scale should not be allowed to accumulate on the face of the plug.

The plugs should be placed in the back head, in rear combustion chamber, well exposed at highest point on the fire line, which should be slightly above top row of tubes.

Q. 106. (1898-9.) Give size of "stack" adapted for 200 HP, i. e., for boilers proposed in Q. 93, height of chimney assumed at 100 ft.

Ans. 106. For 200 HP boilers referred to in Q. No. 93, the diameter for chimney corresponding to a height of 100 ft. should be 38 inches. This assumes the consumption of 5 lbs. good coal per HP per hour and therefore provides for overload and other contingencies as to the quality of the fuel. (Kent's Formula.)

Q. 107. (1898-9.) What is claimed for the modern steel chimney, as compared with well-constructed brick chimneys?

Ans. 107. The advantages claimed for the modern steel chimney over similar brick structures are: Greater strength; less space required; foundations smaller; the cost is less, and furthermore, the draft is not impaired by infiltration of air. Steel chimneys are smaller, lighter and offer less area to wind pressure and are also better adapted to stand the strains, due to unequal temperatures, etc.

Q. 108. (1898-9.) Explain the distinction between "forced" and "induced" draught; state briefly the advantages of both systems when acquired "mechanically," i. e., by fan blowers.

Ans. 108. Under "forced" draft the air is forced through the fire, the pressure above the atmosphere being maintained either in the closed ash-pit or in the closed fire-room. The latter arrangement is only practical in marine service.

Under the "induced" or suction method the products of combustion are exhausted from the furnace, a partial vacuum is produced therein and air thereby caused to flow through the fuel.

Both systems of "mechanical draft" operate to produce a pressure difference between the ash-pit and the combustion chamber, and other things being equal, there is no conclusive evidence that one method is superior to the other; the one to be adopted must depend upon the conditions and the advantages as compared with "chimney draft" are common to either.

In operation, the primary advantage of a mechanical system lies in its intensity and its controllability. Intense draft such as may be readily produced by means of a fan makes possible the burning of the cheapest fuel, which is always mostly in fine particles and packs closely on the grate. It is also conducive to higher rates of combustion and the carrying of deeper fires. A deep fire gives better opportunity for contact between the air and the fuel so that the air supply can be reduced and the efficiency of the plant increased.

Ample draft for the prevention of smoke can be best produced by mechanical means, which at the same time prevents the formation of carbonic oxide.

With a chimney the temperature of the gases must be high to insure sufficient draft, whereas with the fan the gases may be cooled to the lowest possible degree and the heat transferred to the feed water or the air supply, thereby greatly reducing the loss usually resulting from this cause. It is claimed also that the exhaust steam from the fan engines may be utilized and the expense of producing draft by the heat savings noted, is reduced to practically nothing.

Mechanical draft can be automatically regulated to instantly change both the intensity of the draft and the volume of the air. It is thus entirely independent of the conditions of weather and is capable of responding to sudden demands. By its use a given boiler plant may be instantly and greatly increased in capacity to meet such demands as are common in electric railway work. Reserve capacity can thus be stored in light and comparatively cheap fans rather than in ponderous and expensive boilers. When the plant is properly designed less boilers are required than with the ordinary chimney, for a higher combustion rate and greater evaporative capacity can be secured.

Q. 109. (1898-9.) What difficulties attending "hand firing" are overcome by mechanical stokers?

Ans. 109. Mechanical "stokers" feed the fuel with constant regularity; they obviate the frequent opening of fire doors with the usual inrush of cold air; the fires are practically self-cleaning, and by properly arranged coal and ash handling machinery the cost of steam production may be much reduced.

Stokers have to be judiciously selected, maintained and properly run or they may be a source of annoyance and expense.

Q. 110. (1898-9.) Name what considerations should govern the distance between grate and boiler.

Ans. 110. In furnace construction the distance from grate to boiler shell should be governed by the kind of coal to be burned. Anthracite coal requires but 20″ to 24″ for the best results; for semi-bituminous coal the distance should be between 26″ to 30″ and more in proportion for rich bituminous coals.

Q. 111. (1898-9.) What portions of a horizontal tubular boiler should be exposed to the fire and heated gases?

Ans. 111. Only such parts of a horizontal tubular boiler as are protected by water should be exposed to the fire or gases of combustion. This ordinarily includes the lower 3/5 of the shell and such surfaces as are concerned therewith. The return of gases over top of shell does not meet with general favor.

Q. 112. (1898-9.) Explain the meaning of "ultimate tensile strength" and "elastic limit" and state what proportions the latter should bear to the former, in good steel boiler plate.

Ans. 112. "Ultimate tensile strength" is the maximum stress that a piece will endure before being torn asunder. This strength depends somewhat upon the mode of testing; the more rapidly the testing proceeds, the higher will be the apparent strength.

Elastic limit defines the limiting strength, i. e., a load greater than expressed by the elastic limit will produce a permanent elongation or "set" after the load is removed.

The elastic limit for the best grades of boiler steel should be 50% of the tensile strength; the "elongation" varies with the length and thickness of the specimen, but is usually fixed at 25% for plate ⅜″ thickness and thereabouts.

Q. 77. (1899-1900.) What is the effect of increasing the height of a chimney?

How is the difference in pressure measured?

What is the common draft of a chimney as measured in inches of water?

What is the effect of an increase in the difference of pressure or intensity of draft?

What relation would the increase of pressure or intensity of draft have upon the velocity of the gases which flow through the chimney?

Ans. 77. Increasing the height of a chimney increases the intensity of the draft, because it makes a greater difference per unit of base between the weight of the inside column of gases and a column of equal height of the outside air.

The difference in pressure is measured by the height of the column of water it will support; for such a test, a U-shaped tube has one leg connected with the inside of the chimney and the other open to the air; the greater pressure of the atmosphere pushes the water toward the chimney until the difference of the heights of the two columns in the glass tube is sufficient to balance the difference in pressure between the flue and atmosphere. The pressure is measured by taking the difference between the heights of the two columns.

The common draft of a chimney is about ½ in. for ordinary heights and temperatures.

The effect of an increase in pressure, or intensity of draft, is to increase the velocity with which the gases flow through the chimney.

The velocity increases as the square root of the pressure; in order to double the velocity, the pressure would have to be increased 4 times; to get 3 times the velocity, the pressure would have to be increased 9 times.

Q. 78. (1899-1900.) What relation has the height of a chimney to its capacity?

The area of a chimney to its capacity?

How does the area increase?

Give general statement for the capacity of chimney. What effect has temperature upon the capacity?

Ans. 78. The capacity of a chimney varies as the square root of the height.

In a chimney 200 ft. in height, the velocity will be, theoretically, twice as much as a chimney 50 ft. high, so that twice as much gas would be discharged in a given time.

The capacity varies directly as the area—that is, a chimney of twice the cross-section will discharge twice the amount of gas in a given time.

The area increases as the square of the diameter. The capacity varies as the square root of the height and as the square of the diameter.

The effect of temperature on the capacity is that the greater the inside temperature, the greater the difference in pressure and velocity of the gases; but, as the density of the gases decreases with the temperature, there is a point where as much is lost in weight of the gas passed, by the lightness of the gas, as is gained by the increased velocity.

Q. 79. (1899-1900.) How would you find the area required for a chimney of a given height and the number of sq. ft. of grate surface connected? How could the area for a given H.P. be determined?

Ans. 79. Multiply the number of sq. ft. of grate surface by 120, and divide the product by the square root of the height and the quotient will be the required cross-section in square inches.

Divide the H.P. by 3 1-3 times the square root of the height, and the quotient will be the required effective area in square feet.

To the diameter, or length of the required side to give this area, add 4 in., to compensate for friction.

Q. 80. (1899-1900.) What would be the area of a chimney for 55 sq. ft. of grate surface, height being 125 ft., allowing for burning 5 lbs. of coal per H.P. per hour?

Note.—The allowance of 5 lbs. of coal per H.P. per hour is usually made for difference in condition in the atmosphere; also for an increase in demand for extra power, and is the usual base for formulating.

Ans. 80.

125 ft. = height of the chimney.

55 sq. ft. = grate surface.

$$\frac{55 \times 120}{\sqrt{125}} = 595 \text{ sq. in.} = \text{area of cross-section.}$$

$$\text{Diameter} = \sqrt{\frac{595}{.7854}} = 27.4 \text{ in.}$$

Adding 4″ for friction, diameter 27.444 = 31.4 in.

Should a square chimney be called for, then the square root of the area (595 in.) would equal the length of the required side, adding the 4 in. as before.

Should a parallelogram be required in the cross-section of the chimney, having the area (595 sq. in.) given, divide the area by the established length of side, for the side adjacent, adding the 4 in., as before, to both sides.

Q. 91. (1899-1900.) What pressure (draft) will a chimney 135 ft. high produce? Outside temperature 62° F., temperature of flue gases 580° F.

Ans. 91. The province of a chimney is to serve a double purpose of creating a movement of air, or as commonly called, creating a draft, and conducting away the products of combustion or obnoxious gases.

The draft depends upon the gases having a higher temperature, consequently lighter than an equal column of outside air. The air flowing or moving from the place of the higher pressure to that of the lower.

The intensity of the draft depends upon the height of the stack and the difference in temperatures of the outside air and the hot gases in the stack, called the pressure difference.

As an illustration: Take a stack 100 ft. high, outside air at a temp. of 62° F., the gases at a temp. of 570° F.

A pound of burned gas at 62° F. has a volume of about 12.5 cu. ft., while the same gas at 570° F. will have a volume of 22.27 cu. ft.

$$\frac{12.5\ (570^\circ + 460^\circ)}{62^\circ + 460^\circ} = 22.27 \text{ cu. ft.}$$

The 460° representing absolute temperature (some works use 461° as absolute temperature).

A column of gas 100 ft. high with a base of one square foot equals a pressure of $100 \div 22.27 = 4.49$ pounds per square foot.

A pound of air at 62° F. has a volume of 13.14 cu. ft., and a column 100 ft. high and one foot square in section will weigh $100 \div 13.14 = 7.61$ pounds. The pressure difference equals $7.61 - 4.49 = 3.12$ pounds per sq. foot. Equal in oz. pressure to

$$\frac{3.12 \times 16}{144} = .35 \text{ oz.}$$

1 oz. = 1.7295 in. of water.

.35 oz. × 1.7295 = .605 the draft pressure in inches of water.

It will be seen that the higher the stack the lower will be the temperature of the gases in order to obtain the same pressure difference, or the same draft.

The pressure (draft) of a chimney 135 ft. high; outside temp. 62° F.; gases temp. 580° F., may be found by the following formula:

$$P = H\left(\frac{7.6}{T} - \frac{7.9}{Ta}\right) = .945 \text{ inches of water.}$$

Substituting—

$$P = 135\left(\frac{7.6}{522} - \frac{7.9}{1040}\right) = 135\ (.0146 - .0076 = 135 \times .0070 = .945 \text{ inches of}$$

water, the pressure or draft of the chimney.

P = draft in inches of water.

H = height of chimney.

T = absolute temp. outside air (460° + 62°) = 522° F.

Ta = absolute temp. chimney gases (460 + 580)) = 1040° F.

7.6 and 7.9 constants obtained by experiment.

Q. 92. (1899-1900.) A chimney 120 ft. high, temperature flue gases 660° F. It is desirable to add an economizer, which will reduce the temperature of the gases to 390° F. To what height should the chimney be raised in order that the draft will remain the same as at first? Outside temperature in both cases 60° F.

Ans. 92. H = height chimney.

H′ = height chimney after economizer is installed.

T = absolute temp. outside air, 460° + 60° = 520° F.

Ta = absolute temp. gases, 460° + 660° = 1120° F.

Tb = absolute temp. gases after economizer is installed, 460° + 390° = 850° F.

P = pressure in inches of water.

7.6 and 7.9 are constant numbers found in part, by experiment and mathematical process.

$$H\left(\frac{7.6}{T} - \frac{7.9}{Ta}\right) = P \text{ before economizer was installed.}$$

$$H'\left(\frac{7.6}{T} - \frac{7.9}{Tb}\right) = P \text{ after economizer is installed.}$$

$$H' = \frac{P}{\frac{7.6}{T} - \frac{7.9}{Tb}} \text{ the height of chimney after economizer is installed.}$$

Substituting—

$$P = 120\left(\frac{7.6}{520} - \frac{7.9}{1120}\right) = 120\ (.0146 - .0071) = 120 \times .0075 = .90, \text{ the}$$

pressure in inches of water.

$$H' = \frac{.90}{\frac{7.6}{520} - \frac{7.9}{850}} = \frac{.90}{.0146 - .0093} = \frac{.90}{.0053} = 169.81 \text{ ft.}$$

the height of the chimney after the economizer has been installed.

By the use of another formula we obtain an answer of 168.35 ft.; second, 168.88 ft.; third, 170.52.

A slight variation in the constant numbers probably in disuse of decimals make the slight variation in the different answers.

Q. 94. (1899-1900.) A boiler evaporates 12,468 lbs. of water per hour (feed-water 154° F.) to a steam pressure of 145 lbs. (absolute) per square inch, find the equivalent evaporation?

Ans. 94. The total heat of steam, divided by the latent heat of evaporation of water, at 212° F., gives a multiplier, by which the weight of water actually evaporated is to be multiplied by, to reduce it to the equivalent evaporation of, "from and at 212° F."

This total heat of steam is modified somewhat by circumstances.

From the total heat of steam, subtract the heat units in the feed water, and divide the remainder by the latent heat of evaporation at 212° F.

Solution—

1190.4 B. T. U. equals the number of heat units in steam at 145 pounds pressure absolute.

122.33 B. T. U. equals the number of heat units in water at 154° F.

$1190.4 - 122.33 = 1068.07$, the total heat.

$1068.07 \div 966 = 1.1056$, the factor of evaporation.

12468 lbs. steam $\times$ 1.1056 = 13784.62 lbs., "from and at 212° F.," the equivalent evaporation.

Q. 5. (1900-1901.) Assume you are operating a plant furnishing steam for purposes other than supplying steam for your engine, how would you arrange your coal report so as to charge each department with the proper amount of fuel consumed?

Ans. 5. To answer this question other than as an approximation is beyond the limit of a work of this character. There are plants of this kind where the operator generally takes such methods as he may be possessed of for forming approximate ideas relative to the coal and water consumption.

The indicated power is, of course, first taken care of and the balance is subdivided for different purposes. The first thing requisite is good judgment, and a careful scrutiny of the per cent loss not returned in condensation, etc. By measuring the returning condensation water and steam for each system (by meter or otherwise).

If the returns are returned to the boiler, then the difference between the heat units in the steam and the heat units in the returns will equal the heat units used; these multiplied by the number of pounds of returned condensation equal the total number of heat units used; divide this product by the effective heat units in one pound of coal consumed and the quotient will equal the number of pounds of coal used.

Or, the number of pounds of returned condensation divided by the number of pounds of water evaporated will also give the number of pounds of coal used, providing proper allowance is made for the heat that is returned to the boiler.

Q. 6. (1900-1901.) Give opinion relative to the several advantages and disadvantages of the two general types of boilers, water tube and fire tube.

Ans. 6. The water tube boiler, while not rated at as high efficiency as the return tubular boiler, has an element of safety superior to the return tubular boiler.

It is the tendency at the present day with the multi-cylinder engines to carry extreme high pressures, especially in the marine service. Such boilers must be carefully designed for strength. It is likewise necessary to reduce its weight and size to the lowest possible limit, also the best of material should be used. For carrying high pressures, it is clear to see, for the sake of safety, the Scotch type or any tubular type of boiler must be made extremely heavy and bulky, and much

attention is now being paid to the devising of a new type, which, while retaining the good features of the Scotch type, will be lighter, smaller and cheaper for the same power.

Some of the advantages claimed for water-tube boilers are as follows:

1.—That the portions of the boiler which contain the water are so small in diameter that the material used in the construction can be made comparatively light without impairing the strength. Consequently the heat is transmitted to the water more readily and the danger of burning the iron where it is exposed to the fire is greatly diminished.

2.—There are no riveted joints, and consequently no double thickness of metal exposed to the fire.

3.—That the draught area, being much larger than in the fire-tube boilers, gives ample time for the absorption of the heat of the gases before their exit to the chimney.

4.—That the gases being thoroughly mingled in their passage between the staggered tubes, the combustion is more complete.

5.—That the gases impinging against the heating surface perpendicularly instead of gliding along the same longitudinally, the absorption of heat is more thorough. It is claimed that experiments have proven that a gain of 30 per cent in the efficiency of the heating surface is effected.

6.—That the circulation of water is rapid and all in the same direction, there being no conflicting currents. As a result the temperature of the boiler in all its parts is practically the same and the tendency to deposit scale is materially lessened.

7.—That the water being divided into many small streams in thin envelopes, steam may be raised rapidly.

8.—That the large area of disengaging surface in the drums, together with the fact that the steam is delivered at one end and taken out at the other end, insures dry steam without the aid of any superheating device.

9.—That the water level may readily be kept steady.

10.—That the whole structure is so flexible that the parts may expand and contract without producing strains.

11.—That the division of water into small masses avoids destructive explosions.

12.—That the space occupied by this type of boiler for a given power is much less than in fire-tube boilers.

13.—That by a suitable arrangement of hand and man holes every part of the boiler is accessible for cleaning and repairs.

14.—That the loss of effect from dust collecting on the top of the tubes is far less than in fire-tube boilers, where it collects on the interior surface. In the latter case there is no limit to the amount of dust which may collect, while in the former only a limited amount is retained.

15.—That since no part of the boiler above the water level is exposed to the fire, and because of the absence of deteriorating strains and thick plates and joints in the fire, it is much more durable.

16.—That, being made in sections, it is less cumbrous and much more easily transported and erected.

17.—That a new tube may be easily inserted or most any other repair be made by an ordinary mechanic with ordinary tools.

Q. 7. (1900-1901.) Give rules for selecting material for cylindrical shells, also shell plate formula. Also rules for flat plates.

Give furnace formula.

Give rules for selecting stays, also rules for allowable safe load on stays.

Material for cylindrical shells subject to internal pressure.

Ans. 7. Board of Trade Rules.—Tensile strength between 27 and 32 tons. In the normal condition the elongation is not less than 18 per cent in 10 inches, but should be about 25 per cent; if annealed not less than 20 per cent. Strips 2 inches wide should stand bending until the sides are parallel at a distance from each other of not more than three times the thickness of the material.

Lloyd's.—Tensile strength between the limits of 26 and 30 tons per sq. in. Elongation not less than 20 per cent in 8 inches. Test strips heated to a low cherry-red and plunged into water at 82° F. Must stand bending to a curve the inner radius of which is not greater than 1½ times the plates' thickness.

U. S. Statutes.—Plates of ½-inch thickness and under shall show a contraction of area of not less than 50 per cent; when over ½ inch and up to ¾ inch not less than 45 per cent; when over ¾ inch not less than 40 per cent.

From a paper on boiler construction by Nelson Foley, we find the following comments: "The Board of Trade rules seem to indicate a steel of too high a tensile strength, when a lower and more ductile one can be got; the lower tensile strength limit should be reduced, and the bending test might, with advantage, be made after tempering, and made to a smaller radius. Lloyd's rule for quality seems more satisfactory, but the temper test is not severe. The U. S. statutes are not sufficiently stringent to insure an entirely satisfactory material."

Mr. Foley suggests a material which would meet the following: 25 tons the lowest limit in tension; 25 per cent in 8 inches minimum elongation; radius for bending after tempering equals the plate's thickness.

Shell plate formula:

Board of Trade:

$$P = \frac{T \times B \times t \times 2}{D \times F \times 100} \text{ or } P = \frac{2\,(T\,B\,t)}{100\,(D\,F)}.$$

D = diameter of boiler in inches;
P = working pressure in lbs. per sq. in.;
t = thickness in inches;
B = percentage of strength of joint compared to solid plate;
T = tensile strength allowed for material in lbs. for sq. in.;
F = factor of safety; being 4.5, with certain additions depending upon method of construction.

Lloyd's: $P = \frac{C\,(t - 2)\,B}{D}$

t = thickness of plate in sixteenths.
B and D = same as in previous formula.
C = constant depending on the kind of joint.

When longitudinal seams have double butt straps, C = 20.

When longitudinal seams have double butt straps of unequal width, only covering on one side the reduced section of plate at the outer line of rivets, C = 19.5.

When longitudinal seams are lap-jointed, C = 18.5.

U. S. statutes: $P = \frac{2\,t\,T}{6\,D}$ for single riveting; add 20 per cent for double riveting. Use the same notation as in Board of Trade rules or formula.

Mr. Foley criticises the U. S. statutes as follows: "The rule ignores the riveting, except that it distinguishes between single and double, giving the latter 20 per cent advantage; the circumferential riveting or class of seams is altogether ignored. The rule takes no account of workmanship or method adopted of construction of joints. The factor one-sixth simply covers the actual nominal factor of safety,

as well as the loss of strength at the joint, no matter what the percentage; we may therefore dismiss it as unsatisfactory."

Flat Plates—

The Board of Trade rules for flat surfaces, being based on actual experiment, are especially worthy of respect; sound judgment appears also to have been used in framing them, and will be the only ones given in this work.

Board of Trade:

$$P = \frac{C\,(t+1)\,2}{S-6}$$

P = working pressure in lbs. per sq. in.

S = surface supported in sq. in.

t = thickness in sixteenths of an in.

C = constant.

$C = 125$ for plates not exposed to heat or flame, the stays fitted with nuts and washers, the latter three times the diameter of the stay and two-thirds the thickness of the plate.

$C = 187.5$ for the same conditions, but the washers two-thirds the pitch of the stays, and thickness the same as the plate.

$C = 200$ for the same conditions, but doubling plates in place of washers, the width of which is two-thirds the pitch and the thickness the same as the plate.

$C = 112.5$ for the same condition, but the stays with nuts only.

$C = 75$ when exposed to impact heat or flame and steam in contact with the plates, and the stays fitted with nuts and washers three times the diameter of the stay and two-thirds the plate's thickness.

$C = 67.5$ when the same condition exists, but the stays fitted with nuts only.

$C = 100$ when exposed to heat or flame and water in contact with the plates, and stays screwed into the plates and fitted with nuts.

$C = 66$ for the same condition, but stays with riveted heads.

Furnace Formula:—

Board of Trade.—Long Furnaces:

$P = \dfrac{Ct^2}{(L+1)\,D}$, but not where L is shorter than $(11.5t - 1)$, at which length the rule for short furnaces comes into play.

P = working pressure in lbs. per sq. in.;

t = thickness in inches;

D = outside diameter in inches;

L = length of furnace up to 10 ft.;

C = constant as per following table for drilled holes:

$C = 99000$ for welded or butt-jointed with single straps, double riveted;

$C = 88000$ for butts with single straps single riveted;

$C = 99000$ for butts with double straps single riveted.

Provided, however, that the pressure so found does not exceed that given by the following formula, which applies also to short furnaces:

$P = \dfrac{Ct}{D}$ for all patent furnaces named;

$P = \dfrac{Ct}{3D}\left(5 - \dfrac{12L}{67.5t}\right)$ when with Adamson rings.

$C = 8800$ for plain furnaces;

$C = 14000$ for "Fox"; minimum thickness 5/16 inch, greatest 5/8 inch, plain part not to exceed 6 inches in length;

$C = 13500$ for "Morrison;" minimum thickness 5/16 inch, greatest 5/8 inch, plain part not to exceed 6 inches in length;

C = 14000 for "Purves-Brown;" limit of thickness 7/16 and 5/8 inch; plain part 9 inches in length;

C = 8.800 for Adamson rings; radius of flange next fire 1½ inches.

U. S. Statutes.—Short Furnaces: Plain and Patent. When less than 8 ft. in length:

$$P = \frac{89600t^2}{L D}$$

$$P = \frac{t C}{D} \text{ when}$$

C = 14000 for Fox corrugations where D equals mean diameter.

C = 14000 for Purves-Brown where D equals the diameter of the flue.

C = 5677 for plain flues over 16 inches in diameter and less than 40 inches, when not over 3 ft. in length.

Material for stays:—

Board of Trade.—The tensile strength to lie within the limit of 27 and 32 tons per square inch, and to have an elongation of not less than 20 per cent in 10 inches.

Steel stays, which have been welded or worked in the fire, should not be used.

Lloyd's.—26 to 30 tons, steel, with elongation not less than 20 per cent in 8 inches.

U. S. Statutes.—The only condition is that the reduction in area must not be less than 40 per cent if the test bar is over ¾ inch in diameter.

Safe loads on stays:—

Board of Trade.—9000 lbs. per square inch is allowed on the net section, provided the tensile strength range from 27 to 32 tons.

Steel stays are not to be welded or worked in the fire.

Lloyd's.—For screwed and other stays not exceeding 1½ inches in diameter, effective, 8000 per square inch is allowed; for stays above 1½ inches 9000 lbs. No stays are to be welded.

U. S. Statutes.—Braces and stays shall not be subjected to a greater stress than 6000 lbs. per square inch.

Q. 8. (1900-01.) Give rules for tube plates, finding thickness and distance between tubes; that is, how much material should properly be left between the tubes?

Give rules for establishing the value of material for boiler tubes.

Would you allow for the holding power of boiler tubes due to friction between the outer surface of the tube and the surface of the hole in the tube sheet?

What do you consider as the best form of hole through the tube sheet?

What would be the relation in efficiency between a tube simply expanded in and one expanded in and beaded? That is, as regards the holding power of tube.

Ans. 8. Tube Plates:

Board of Trade rule:

$$P = \frac{t\,(D - d) \times 20000}{W D}$$

D = least horizontal distance between centers of tubes in inches;

d = inside diameter of ordinary tubes;

t = thickness of tube plate in inches;

W = extreme width of combustion-box in inches from front tube-plate to back of fire box, or, distance between combustion box tube plates when boiler is double-ended and the box common to both ends;

P = pitch of tubes;

The thickness of tube plates is generally one-eighth of an inch in excess of the sheet forming the shell of the boiler.

Material for boiler tubes:—

If of iron, the quality to be such as to give at least 22 tons per sq. in. as the minimum tensile strength, with an elongation of not less than 15 per cent in 8 inches. If of steel, the elongation to be not less than 26 per cent in 8 inches for the material before being rolled into strips; and after tempering, the test bar to stand completely closing together. Provided, the steel welds well, there does not seem to be any objection in providing tensile limits.

The ends should be annealed after manufacture and stay-tube ends should be annealed before screwing.

The holding power of tubes:—

Experiments made in the Washington Navy Yard show that, with 2½-inch brass tubes, in no case was the holding power less than 6000 lbs., while the average was upwards of 20000 lbs. It was further shown that with these tubes, nuts were superfluous, quite as good results being obtained with tubes simply expanded into the tube-sheet and fitted with a ferrule.

In five experiments with steel tubes 2 inches and 2¼ inches in diameter, the first five tubes gave way on an average of 23740 lbs., which would appear to be about 2/3 the ultimate strength of the tubes themselves.

In all these cases the hole through the tube-plate was parallel with a sharp edge to it, and a ferrule was driven into the tube.

Another test of five steel tubes made under the same conditions as the first five, with the exception that the ferrule was omitted, the tubes simply being expanded into the plate. The mean pull required 15270 lbs., or considerably less than half the ultimate strength of the tubes.

The effect of beading the tubes, the holes through the plate being parallel and ferrules omitted. The mean of the first three, which are tubes of the same kind, gives 26876 lbs. for the holding power, under these conditions, as compared with 23740 lbs. for tubes fitted with ferrules only. This high figure is, however, due mainly to an exceptional case when the holding power is greater than the average strength of the tubes themselves.

It is disadvantageous to cone the hole through the tube-plate unless the sharp edge is removed, as the results are much worse than those obtained with a parallel hole.

In experiments on tubes expanded into tapered holes and simply beaded over, better results were obtained than with ferrules; in these cases, however, the sharp edge of the hole was rounded off, which appears in general to have a good effect.

Experiments by Yarrow & Co.:

In fifteen experiments on 4 and 5-inch steel tubes, the strain ranged from 20720 to 68040 lbs. Beading the tubes does not necessarily give increased resistance, as some of the lower figures were obtained from beaded tubes.

Q. 9. (1900-01.) What controls the diameter of rivets, and what is the extreme limit of their pitch?

What should be the thickness of double butt straps (each) and what should be the thickness of single butt straps?

What should be the distance from edge of plate to the center of rivet holes?

What should be the distance between the rows of rivets when chain riveted and when zig-zag riveted?

Ans. 9. For Single-Riveted Plates.—Lap Joint:

The diameter of the hole should be two and one-third (2 1-3) times the thickness of the plate, and the pitch of the rivet two and three-

eighths times the diameter of the hole, making the mean plate area 71 per cent of the rivet area.

For double-riveted lap-joints:

The ratio of diameter to thickness remains the same as in single-riveted lap-joints; while the ratio of pitch to diameter of hole should be 3.64 for 30-ton plates, and 22 and 24 ton rivets, and 3.82 for 28-ton plates with the same rivets.

The distance from the edge of plate to center of rivet hole should be 1½ diameters.

The thickness of double butt straps should be at least ⅝ of the thickness of the plate, and for single-butt straps the thickness should be 1⅛ times the thickness of the plate.

"Kent" gives the following formula for the pitch:

$$\text{Single riveted plates } P = .571\frac{d^2}{t} + d$$

$$\text{Double riveted plates } P = 1.142\frac{d^2}{t} + d$$

P = pitch of the rivets;
d = diameter of hole;
t = thickness of plate;

The co-efficients .571 and 1.142 agree closely with those given in the report of the committee of the Institution of M. E.

Distance between rows of rivets in chain riveting =

$$D = 2 \times \text{diam. of rivet, or } \frac{[(\text{diam.} \times 4) + 1]}{2}$$

Zigzag =

$$D = \sqrt{[(\text{pitch} \times 11) + (\text{diam.} \times 4)] \times (\text{pitch} + \text{diam.} \times 4)}$$

$$\text{Diagonal pitch} = \frac{(\text{pitch} \times 6 + \text{diam.} \times 4)}{10}$$

Note.—The subject of riveting, in its many forms of joints and conditions, is exhaustless, and to do proper justice to the subject is not within the province of this work, and to those seeking a thorough knowledge on this subject, the standard authorities should be consulted.

Q. 10. (1900-01.) What is your opinion of iron versus steel boiler tubes?

Give rule for finding allowable pressure on bumped heads of boilers.

Ans. 10. A good grade of charcoal iron makes the best boiler tube.

Mild homogenous steel is used to a great extent and makes a very good tube.

If wrought iron is used, it should have a tensile strength of not less than 45000 pounds per sq. in., and an elongation of 15 per cent in 8 inches, and after tempering the test bar should stand completely closing together.

Experiments seem to indicate that, so far as leakage is concerned, iron is preferable because it is not subject to the same degree of expansion and contraction as steel.

Bumped Heads:

In the construction of bumped heads for boilers, in order that the head should have the same strength as the shell, the head should be bumped; that is, the spherical part of the head should be curved to a radius equal to the diameter of the boiler. Should a larger radius be used the tendency would be to weaken the boiler.

The nearer hemispherical the head is the stronger it is.

Rules for allowable pressure:

Multiply the thickness of the plate by 1/6 of the tensile strength and divide this product by 6/10 of the radius, to which the head is bumped, which will give the pressure per sq. in. allowable.

Q. 11. (1900-01.) What should be the tensile strength (T. S.) elongation and contraction of area of the materials for rivets?

What shearing resistance per square inch, and what factor of safety should be used for steel rivets?

What difference should be allowed in the calculations between rivets in single and double shear?

Ans. 11. Rules Connected with Riveting:

Board of Trade.—The shearing resistance of the rivet steel to be taken at 23 tons per sq. in., 5 to be used as a factor of safety independently of any addition to this factor for plating. Rivets in double shear to have 1.75 times the single section taken in the calculation instead of 2. The diameter must not be less than the thickness of the plate and the pitch never greater than 8½ inches.

Lloyd's.—The shearing strength of rivet steel to be taken at 85 per cent of the tensile strength.

The tensile strength of rivet bars between 26 and 30 tons, with an elongation in 10 inches of not less than 25 per cent and a contraction in area not less than 50 per cent.

Q. 12. (1900-01.) Give rules for proportioning the areas of flues, tubes and other gas passages for both anthracite and bituminous coals.

For air passages in grate bars.

Ans. 12. For anthracite coal 1/9 to 1/10 of the grate surface.

For bituminous coal 1/6 to 1/7 of the grate surface.

The tube or flue area should be of sufficient area so as not to impede the passage of the gases and not impair the efficiency of the boiler.

If too large, there is a tendency for the gases to select passages of the least resistance, escaping without wholly giving up their heat, also impairing the efficiency of the boiler.

The grate bars are usually constructed with an allowance of 45 to 55 per cent air space. Some forms of construction require more air space than others.

Q. 13. (1900-01.) How is the working pressure of a boiler calculated from the pressure of the usual hydrostatic test?

What are the several rules used in establishing the nominal factor of safety in boiler construction?

Ans. 13. The hydrostatic test, as applied to boilers, is usually 1½ times the working pressure of the boiler.

Nelson Foley proposes that the proof pressure should be 1½ times the working pressure plus one atmosphere (15 lbs.).

The rules for finding factor of safety are somewhat conflicting. The factor of safety equals the bursting pressure of the boiler as figured by the rules before given, divided by the working pressure for which the boiler is built.

The factor is usually considered in connection with the tensile strength of the material, the character of the joint and the workmanship, and range from 3½ per cent upward, according to conditions.

Q. 14. (1900-01.) The term "horse-power" as applied to steam boilers, means the capacity of a boiler to evaporate 30 pounds of water from and at a temperature of 100° F. into steam of 84.7 pounds absolute pressure per square inch.

What should be the average proportion for maximum economy, hand firing, good anthracite coal, of—

Heating surface per horse power?

Grate surface per horse-power?

Ratio of heating to grate surface?

Water evaporated from and at 212° F. per square foot of heating surface per hour?

Combustible burned per horse-power per hour?

Combustible burned per square foot of grate surface per hour?

Coal with 16 2/3 % refuse in pounds per hour?

Coal with 16 2/3 % refuse in pounds per hour per square foot of grate surface?

Water evaporated from and at 212° F. per pound of combustible?

Water evaporated from and at 212° F. per pound of coal, 16 2/3 % refuse?

Ans. 14. Steam Boiler Proportions (as per conditions of Question 15).

Heating surface per horse-power, 11.5 sq. ft.
Grate surface per horse-power, 1/3 sq. ft.
Ratio of heating to grate surface, 34.5 to 1.
Water evp'd from and at 212° per sq. ft., H. S. per hour, 3 lbs.
Combustible burned per H. P., per hour, 3 lbs.
Coal with 16 2/3 % refuse, lbs. per hour, 3.6 lbs.
Per sq. ft. grate surface, 10.8 lbs.
Combustible burned, per sq. ft. grate surface, 9 lbs.
Water evaporated from and at 212° per lb. comb., 11.5 lbs.
Water evaporated from and at 212° per lb. coal, 9.6 lbs.

Q. 15. (1900-01.) Specify the thickness of sheets or plates, style of seams, braces, size of rivets, pitch, etc., together with the diameter and length of shell, the diameter and number of tubes, for a horizontal tubular boiler, builders rating 150 horse-power, maximum working pressure to be 120 pounds per square inch, gauge pressure.

Which is advisable to use, a drum or nozzle?

Ans. 15. Under conditions of the questions:

A boiler 72 inches in diameter, 17 feet long, 132 3-inch tubes; heating surface 1800 sq. ft. The sheets ½ inch in thickness of "open hearth fire-box steel," with tested tensile strength of 60000 lbs. per sq. in. of section.

Horizontal seams—"triple-riveted double butt-joint;" holes drilled 1 inch in diameter; rivets 15/16 inch in diameter; pitch of rivets 3¾ inches by 7½ inches. The efficiency of joints, 86.6 per cent.

Through bracing from head to head.

Heating surfaces:

$$\text{One-half shell} = \frac{6 \times 3.1416 \times 17}{2} = 160.21 \text{ sq. ft.}$$

Area of heads = 37.7 sq. ft.

Area of tube ends in both heads equals 6.48 × 2 = 12.96 square feet.

Deducted from head area equals:

37.68 — 12.96 = 24.72 sq. ft. heating surface on heads.

The inner diameter of 3-inch tube equals 2.78 inches.

Heating surface per ft. in length equals 2.78 × 3.1416 ÷ 144 = .7283 sq. ft. per foot length.

Sq. ft. heating surface in each tube equals .7283 × 17 = 12.38 sq. ft.

Total heating surface in tubes equals 12.38 × 132 = 1634.16 sq. ft.

Total heating surface of the boiler:

Shell, 160.21 sq. ft.; heads, 24.72 sq. ft.; tubes, 1634.16 sq. ft.; total, 1819.09 sq. ft. of heating surface.

The nozzle is used in preference to the dome. The steam dome has

a tendency to weaken the shell of the boiler and has not proved of any real value in providing dry steam for the engine.

Q. 16. (1900-01.) Give a description of what you consider a first-class typical boiler setting for a horizontal tubular boiler of given dimensions, with total area and height of chimney included (for natural draft).

Ans. 16. Boiler Setting.—Return Tubular:

In a boiler setting, three things are to be obtained:

First—A firm support for the boiler shell; this of course includes foundations, walls and all necessary supports.

Second—A properly proportioned and arranged ash-pit, furnace and combustion chamber.

Third—A protected covering for the boiler, which shall, as far as possible, prevent the loss of heat by radiation.

The Hartford Boiler Insurance Company describes the setting of a 60-inch horizontal return-tubular boiler as follows:

"The foundation is heavy stone work laid to the depth of three to four feet below the surface. Upon this the brick work is laid.

"The side and rear walls are double, with a two-inch air space between the inner and outer walls; there are projecting brick laid in these walls, simply to steady the brick work, but not to interfere with the expansion of the inner wall, caused by the extreme furnace heat.

"The inside wall next to the furnace, and hot gas passage is faced with fire brick.

"The bridge wall in some instances is built wholly of fire brick; in other cases faced.

"The boiler is supported by cast-iron lugs, riveted to the shell. These lugs rest upon iron plates placed upon the tops of the side walls.

"The front lugs rest directly upon the plates, while the back lugs rest upon rollers of one inch round iron allowing free expansion and contraction of the boiler.

"The rear wall is 24 inches from the rear head of the boiler, allowing ample space for the gases to enter the tubes; above the tubes, however, the wall is built in to meet the head, and forms a roof for the chamber.

"The rear wall is provided with a door, to remove the dirt and soot that collects back of the bridge, and also to provide means for inspection.

"For anthracite coal the grate is placed 24 inches below the shell. For bituminous 28 to 30 inches.

"The grate has a fall of three inches from front to rear, so that the fuel is thicker near the back end of the fire; this is believed to lead to more even combustion, since the air has naturally a greater tendency to pass through the fire nearest the bridge, and upon meeting a thick bed of coals its passage is somewhat retarded.

"The end of the boiler which contains the man-hole or hand-hole should be set one inch lower than the other end; this aids the flow of the water and sediment toward the man-hole through which it can be removed.

"The brick-work is closed into contact with the shell at the level of the center of the upper row of tubes; this prevents the gases coming in contact with the plates above the water-line.

"A safe rule is, Never expose to fire or gases of combustion any part of the shell not completely covered with water.

"The brick work is strengthened by buck-staves held together by tie-rods. The buck-staves are of wrought iron, channel or angle irons.

"In the matter of covering: the tops of boilers and other portions

of the surface not in contact with furnace gases should be covered with some non-conducting substance to prevent the radiation of heat.

"A chimney 30 inches in diameter, or its equivalent area, if square (706.9 sq. in.), with a height of 90 feet, will be ample for a boiler of this size.

"The location of a chimney oftentimes should govern the height. A chimney should have height enough so that the draught should not be impaired by surrounding objects."

Q. 17. (1900-01.) Give full detailed description of how you would conduct a boiler test, accompanied by a report, either genuine or fictitious, hand firing.

Give rule for finding the factor of evaporation.

Ans. 17. Boiler Tests—

First—In preparing or conducting trials of steam boilers the specific object of the proposed trial should be clearly defined and steadily kept in view.

Second—Measure and record the dimensions, positions, etc., of grate and heating surfaces, flues, chimneys, proportion of air space in the grate surface, kind of draught, natural or forced.

Third—Put the boiler in good condition, have heating surface clean inside and out, grate-bars and sides of furnace free from clinkers, ashes and dust removed from back connections, all leaks in masonry stopped and all obstructions to draught removed. That the damper will open to full extent, and that it will close when it is desired.

Fourth—Have an understanding in regard to the character of coal to be used. The coal must be dry; if wet a sample must be dried carefully and the per cent of moisture be obtained, to correct finally the results of the test.

Fifth—In all important tests a sample of coal should be selected for chemical analysis.

Sixth—Establish the correctness of all apparatus used in testing, weighing or measuring. These are: (1) scales for weighing; (2) tanks, or water meters (water meters as a rule should be used only as a check on other measurement); for accurate work the water should be weighed or measured in a tank; (3) thermometers and pyrometers for taking temperatures of air and steam, feed water, waste gases, etc.; (4) pressure gauges, draught gauges, etc.

Seventh—Before beginning the test, the boiler and chimney should be thoroughly heated to their usual working temperature. If the boiler is new, it should be in continuous use at least one week before testing, so as to dry the mortar thoroughly and heat the walls.

Eighth—Before beginning a test all superfluous pipes and connections should be disconnected (including the blow-off), or stopped with a blank flange, unauthorized opening of valves should be guarded against. If an injector is used, it must receive the steam directly from the boiler under test. See that the steam pipe is so arranged that the water from condensation cannot return to the boiler. If necessary, it must be trapped.

Starting and Stopping a Test:

A test should last at least ten hours of continuous running and longer if practicable. The conditions of boiler and furnace in all respects should be, as nearly as possible, the same as at the beginning of the test. The steam pressure and the water-level kept the same, the fires should be kept as near as possible the same; in fact, all conditions as enumerated kept the same.

Standard Method:

Is to pull the fires, the steam being raised to the proper pressure, and the water-level at the proper point. Close damper and clean ash-pit, etc. Rebuild with weighed wood and coal, noting the time and

all conditions of water and steam. At the end of the test remove the fire and ashes as at the beginning of the test, and make notes of all conditions, etc.

An Alternate Method:

Clean the fires, and note all conditions as in the standard method, and at the end of the test the fires should be burned low, as at the beginning of the test and all other conditions observed.

During the test:

"A." Keep all conditions uniform; the boiler should be run continuously, without stopping for meal-times or for rise or fall of pressure of steam due to the change of demand for steam. The draught being adjusted to the rate of evaporation or combustion desired before the test is begun, it should be retained constant during the test by means of the damper.

If the boiler is not connected to the same steam pipes with other boilers, an extra outlet for steam with valve in same, should be provided, so that in case the pressure should rise to that at which the safety-valve is set, it may be reduced to the desired point by opening the extra outlet without checking the fires.

If the boiler is connected to the same steam pipe with other boilers, the safety-valve on the boiler being tested should be set a few pounds higher than those on the other boilers, so that in case of a rise in pressure the other boilers will blow off, and the pressure be reduced by closing their dampers, allowing the damper on the boiler to remain open.

Conditions must be kept uniform. Should (owing to the character of the coal) the fires need cleaning during the test, the time and all conditions should be noted.

Keeping the Records:

The coal should be weighed and delivered to the fireman in equal portions, each sufficient for one hour's run, and a fresh portion should not be delivered until the previous one has all been fired, noting the time required to consume each portion.

It is desirable that at the same time that the amount of water fed into the boiler should be accurately noted and recorded, the height of the water, and steam pressure, and temperature of the feed water (average).

By thus recording the amount of water evaporated by each successive portions of coal, the record of the test may be subdivided into divisions, if desired, and at the end of the test to discover the degree of uniformity of combustion, etc., at the different stages of the test.

Priming Tests.—Calorimeter tests should be made to ascertain the percentage of moisture in the steam or of the degree of superheating. At least ten such tests should be made, and the greatest care should be taken in the measurements of weights and temperature.

Analysis of Gases.—Measurements of air supply. For commercial purposes are not necessary, only in cases of scientific research.

These are the measurements of the air supply, the determination of its contained moisture, the measurement and analysis of the flue gases, the determination of the amount of heat lost by radiation, of the amount of infiltration of air through the setting, the direct determination by calorimeter experiments of the absolute heating value of the fuel and (by condensation of all steam made in the boiler) of the total heat imparted to the water.

The analysis of the flue gases is an especially valuable method of determining the relative value of different methods of firing or of different kinds of furnaces.

The final results should be recorded upon a properly prepared blank and should include all the items as are adapted for the specific object for which the test is made.

REPORT OF ACTUAL BOILER TEST.

Credited to "Mass. No. 17, Lowell," under A. S. M. E. Code, Standard test.

Babcock and Wilcox boiler, with B. & W. regular setting plain grates.

Coal used, "Georges Creek," Cumberland, of good quality.

Grate surface, 67.6 sq. ft.

Water heating surface, 3,195 sq. ft.

Builders' rating, 319.5 H. P.

TOTAL QUANTITIES.

1. Date of trial, May 30, 1899.
2. Duration of trial, 12 h.
3. Weight of coal fired, including equivalent wood, 14,966 pounds.
4. Percentage of moisture in coal, 3.1 per cent.
5. Total weight dry coal consumed, 14,537 pounds.
6. Total ash and refuse, 1,165 pounds.
7. Percentage of ash and refuse, 8.1 per cent.
8. Total weight of feed water, 137,266 pounds.
9. Water actually evaporated, corrected for moisture in steam, 136,580 pounds.

9a. Factor of evaporation, 1.1913.

10. Equivalent water evaporated into dry steam from and at 212° F., 162,708 pounds.

HOURLY QUANTITIES.

11. Dry coal consumed per hour, 1,211 pounds.
12. Dry coal per sq. ft. grate sur., per hour, 17.9 pounds.
13. Water evaporated per hour, corrected for quality of steam, 11,382 pounds.
14. Equivalent evaporation per hour from and at 212° F., 13,565 pounds.
15. Equivalent evaporation per hour from and at 212° F., per sq. ft. water heat surface, 4.25 pounds.

AVERAGE PRESSURE, TEMPERATURE, ETC.

16. Steam pressure by gage, 91.9 pounds.
17. Temperature of feed water entering boiler, 66° F.
18. Temp. of escaping gases from boiler, 386° F.
19. Force of draught between boiler and damper, .7 inch.
20. Percentage of moisture in steam, 5 per cent.

HORSE-POWER.

21. Horse-power developed, 393 H. P.
22. Builders' rating H. P., 319.5 H. P.
23. Percentage of builders' rating developed, excess, 23 per cent.

ECONOMIC RESULTS.

24. Water apparently evaporated under actual conditions per pound of coal as fired, 9.15 pounds.
25. Equivalent evaporation from and at 212° F., per pound of coal as fired, 10.85 pounds.
26. Equivalent evaporation from and at 212° F., per pound of dry coal, 11.19 pounds.
27. Equivalent evaporation from and at 212° F., per pound of combustible, 12.17 pounds.

EFFICIENCY.

28 (assumed). Calorific value of dry coal, per pound, 14,000 B. T. U.

29 (assumed). Calorific value of the combustible per pound, 15,134 B. T. U.

30. Efficiency of boiler (based on combustible), 77.6 per cent.

31. Efficiency of the boiler, including grate (based on dry coal), 77.1 per cent.

COST OF EVAPORATION.

32. Cost of coal per ton (2,240 pounds), $3.40.

33. Cost of coal required to evaporate 1,000 pounds of water from and at 212° F., $0.136.

The Factor of Evaporation is the difference between total heat of the steam at the observed pressure and the total heat of the feed water at the observed temperature, divided by 965.7.

Formula. $\frac{H\text{-}h}{965.7}$ = Factor of evaporation.

H = the total heat of steam at the observed pressure.

h = the total heat of feed water at the observed temperature.

965.7 = Latent H. U. in steam, atmospheric pressure.

Q. 18. (1900-01.) If your test should show that you were evaporating fourteen pounds of water per pound of coal, or six pounds of water per pound of coal, would you regard these results with suspicion, and if so, why?

Ans. 18. In the common forms of horizontal tubular land boilers and water-tube boilers, with ample horizontal drums, supplied with water free from substance likely to cause foaming, the moisture in the steam does not usually exceed 2 per cent, unless the boiler is overdriven or the water level carried too high.

If, in an evaporative test, it was found that fourteen pounds of water was being evaporated per pound of coal, the result would be deemed erroneous, and another test should be made, subject to a calorimetric correction for the unprecedented amount of moisture in the steam. There are not sufficient number of H. U. in coal to evaporate 14 pounds of water per pound of coal.

On the other hand, there might be losses enough to reduce the evaporation down to 6 lbs. per pound of coal, which should be sought out and corrected at once.

Q. 19. (1900-01.) What is the difference between incrustation and corrosion? Define, and give causes for each; also good practice with respect to prevention of each.

Ans. 19. Incrustation is due to the presence of salts in the feed water (carbonates and sulphates of lime and magnesia for the most part), which are precipitated when the water is heated, and form hard deposits upon the boiler plates.

Corrosion (internal):

In marine boilers corrosion is generally due to the combined action of salt water and air when under steam, and when not under steam to the combined action of air and moisture upon the unprotected surfaces of the metal. Other deleterious influences are at work, such as the corrosive action of fatty acids, the galvanic action of copper and brass, and the inequalities of temperature; these latter are considered of minor importance.

There is a condition where a boiler is badly scaled, the high temperature required to form steam predisposes the material forming the boiler to oxidize rapidly.

The higher the temperature at which iron or steel is kept, the more rapidly it oxidizes, and at a heat of 600° F. it soon becomes granular and brittle, and is liable to bulge, crack, or otherwise give way from the internal pressure.

As a preventative from scale formation, no general rule can be given; it is only through a careful analysis of the feed water that the proper antidote is found. There are also mechanical appliances known as "live steam purifiers," by the use of which the impurities are precipitated and blown off before reaching the boiler proper. When the quantity of these salts is not very large (say 12 grains per gallon) scale preventatives may be found effective. The chemical preventatives either form with the salts, other salts soluble in hot water, or precipitate them in the form of soft mud, which does not adhere to the plates, and can be blown and washed out at times. The selection of the chemical must depend upon the analysis and be introduced regularly with the feed.

The preventation of corrosion in a boiler is a subject upon which there is a diversity of opinion. A boiler in use, especially where returns from heating systems and otherwise, or where pure water is used which has a tendency toward oxidization, should be mixed with a certain quantity of the regular service water; some propose that a boiler after cleaning should be coated with some compound as a wash of Portland cement, to form a thin hard scale to protect the iron from corrosive action, etc., etc.

Boiler laid up in ordinary. There are also different opinions as to which is the proper mode of procedure. If a boiler could be thoroughly cleansed and dried and kept dry, it would probably be as good a way as any, but in connection with other boilers, there is more or less vapor from leaky stop valves and it is impossible to keep all parts of the boiler in a dry condition; in a case of this kind I would suggest the following mode of procedure: The boiler being cleaned, fill with water and attach a ¼-inch steam pipe at the highest point and keep the boiler under pressure at all times.

Q. 20. (1900-01.) Would you regard a boiler compound offered for universal use as safe to use?

What may be considered as a proper preventative under any and all possible conditions?

Ans. 20. A boiler compound offered for universal use should be condemned. As a proper preventative to be used at all times and under all circumstances; again there is a divergence of opinion. Generally the usual substance in water can be retained in soluble form, or be precipitated as mud by using caustic soda or lime. This is especially desirable when the boilers have small interior spaces.

Some of the products of petroleum are highly advocated by some, others condemn it. Kerosene (refined) contains more or less of the acids used in the refining process, yet, still it is recommended.

Crude petroleum of the grade known as rock oil is probably the best product of the petroleum series; the grade known as surface oil should be barred, as it contains explosive gases, and its tarry constituents are apt to form a spongy incrustation.

Care should be taken on opening up a boiler or its connections at any time when these oils have been used, to guard against explosions of gas. Lights, cigars and pipes should be left in the background and the boiler have ample time to air out.

Q. 24. (1900-01.) Assume a coal, either anthracite or bituminous, having 5 per cent moisture, 15 per cent refuse and the balance combustible capable of being transformed into $C O_2$ at the rate of 14,544 B. T. U. per pound. Assume, also, that one horse-power requires 2545 heat units per hour, how many pounds of said coal will be required for 1200 horse-power per day of twelve hours? No allowance being made for banking fires and waste due to cleaning, etc.

Ans. 24. $100 - (15 + 5) = 80\%$ the thermal efficiency of the coal.
$14544 \times 80 = 11635.2$ H. U. in 1 pound of the coal.
$2545 \times 1200 \times 12 = 36{,}648{,}000$ heat units required under conditions of question for 1200 H. P. for a run of 12 hours.
$36{,}648{,}000 \div 11635.2 = 3149.7525$ pounds of coal required per day of 12 hours for 1200 H. P.
This amount of coal consumed of course looks ridiculous, and the only assumption would be that this consumption of coal was based upon a theoretically perfect boiler, and an engine working to the absolute zero with no condensation or radiation losses.
Should we assume that this engine working 1200 H. P. for day of 12 hours had a thermal efficiency of 9 %;
Then will 36,648,000 H. U. equal 9 % of the total heat-units in the entire amount of coal consumed;
Then will 100 %, or total consumption of coal equal

$$\frac{36{,}648{,}000 \times 100}{9} = 34{,}997 \text{ pounds} = 17.49 \text{ tons of coal of } 2{,}000 \text{ lbs. per}$$

ton, required for 1200 H. P. for a day of 12 hours.

Q. 27. (1900-01.) What is the common cause of smoke and what is smoke called when deposited on solid bodies?

Ans. 27. The ingredients of every kind of fuel commonly used may be classed:
First—Fixed or free carbon, which is left in the form of charcoal or coke after the volatile ingredients of the fuel have been distilled away.
These ingredients burn either wholly in the solid states (C to CO_2), or part in the solid state and part in the gaseous state ($CO + O = CO_2$), the latter part being first dissolved by previously formed carbonic acid by the reaction, $CO_2 + C = 2\,CO$.
Carbonic oxide, C O, is produced when the supply of air to the fire is insufficient.
Second—Hydro-carbons, such as olefiant gas, pitch, tar, naphtha, etc., all of which must pass into the gaseous state before being burned.
If mixed on their first issuing from amongst the burning carbon with a large quantity of hot air, these inflammable gases are completely burned with a transparent blue flame, producing carbonic acid and steam. When mixed with cold air they are apt to be chilled and pass off unburned. When raised to a red heat, or thereabouts, before being mixed with a sufficient quantity of air for perfect combustion, they disengage carbon in fine powder, and pass to the condition partly of marsh gas and partly of free hydrogen, and the higher the temperature the greater is the proportion of carbon thus disengaged.
If the disengaged carbon is cooled below the temperature of ignition before coming in contact with oxygen, it constitutes, while floating in the gas, "smoke," and when deposited on solid bodies "soot."

Q. 28. (1900-01.) What occurs when the disengaged carbon is maintained at the temperature of ignition and supplied with sufficient oxygen for its combustion?

Ans. 28. If the disengaged carbon is maintained at the temperature of ignition and supplied with oxygen sufficient for its combustion, it burns while floating in the inflammable gas, and forms red, yellow or white flame. The flame from the fuel is the larger the more slowly its combustion is effected. The flame itself is apt to be chilled by radiation from the heating surface of a steam boiler, so that the combustion is not completed, and part of the gas and smoke pass off.

Q. 29. (1900-01.) Does the flame from the fuel come into contact with the fire sheets of a horizontal tubular boiler, or the outer surface of the tubes of a water tube boiler, or does it penetrate into the tubes of any type of fire tube boilers?

Ans. 29. In the use of wood and similar class of fuels there is no doubt but what the flame comes into contact with the fire sheets of the boiler, also the tubes and sometimes the stack.

In the use of coal (anthracite and semi-bituminous) the flame proper is hardly long enough to either strike the sheets or penetrate the tubes.

In mixing the hydro-carbons with the necessary amount of air the product of perfect combustion takes place and the flame encircles the exposed sheets, penetrates the tubes, especially in case of hard driven boilers.

Q. 30. (1900-01.) Can secondary combustion take place in the back connections or flues?

Ans. 30. As we have been taught that combustion is the chemical combination of the constituents of the fuel, mostly carbon and hydrogen, with the oxygen of the air. The nitrogen in the air remains inert and causes loss of useful effect to the extent of the heat it carries off through the chimney.

The hydrogen combines with the proportional part of oxygen to form water which passes off as steam.

The carbon combines with enough oxygen to form perfect combustion, or with only enough to form imperfect combustion.

To insure perfect combustion the sufficient quantity of air having been admitted and properly mixed with the fuel solid and gaseous, and these, the air and combustible gases should be brought together and maintained at a sufficiently high temperature. The hotter the elements the greater is the facility of good combustion.

If perfect combustion ensues there is no need of secondary combustion in the back connections and flues.

If imperfect combustion takes place, then a portion of the mixed air and gases pass off unconsumed; now, unless a proportional amount of air can be admitted and mixed with this product, and the temperature raised to and above the point of ignition secondary combustion will not take place. Secondary combustion is desirable, and there has been various devices and settings introduced at various times to accomplish this result, but the gain has not warranted their continuance or extended use.

Q. 31. (1900-01.) What is the comparative value of coal and oil as fuel from the evaporation standpoint, also from the standpoint of economy in cost?

Ans. 31. In 1892 there were reported to the Engineers' Club, Philadelphia, some comparative figures from tests undertaken to ascertain the relative value of coal and oil as a fuel.

1 lb. anthracite coal evaporated from and at 212° F., 9.70 lbs. water.

1 lb. bituminous coal evaporated from and at 212° F., 10.14 lbs. water.

1 lb. oil evaporated from and 212° F., 16.48 lbs. water.

Taking the efficiency of the bituminous coal as a basis the calorific energy of petroleum is more than 60 % greater than that of coal; whereas, theoretically, petroleum exceeds coal only 45 %, the one containing 14500 H. U. and the other 21000 H. U.

As a result of tests made by the Twin City Rapid Transit Company of Minneapolis and St. Paul, showed that with the ordinary Lima oil weighing 6.6 lbs. per gallon, and costing 2¼ cents per gallon, and coal that gave an evaporation of 7½ lbs. of water per pound of coal, the

two fuels were equally economical when the price of coal was $3.85 per ton of 2,000 lbs. With the same coal at $2.00 per ton, the coal was 37 per cent more economical than the oil.

With the coal at $4.85 per ton the coal was 20 % more expensive than the oil. These results include the difference in the cost of handling the coal, ashes and oil.

Q. 43. (1900-01.) Calculate what percentage of the energy contained in the fuel is utilized in a steam plant consisting of a boiler which evaporates eight pounds of water per pound of fuel, and an engine which consumes twenty-five pounds of steam per IHP. per hour. The fuel contains 10,000 B. T. U. per pound.

Ans. 43. Pounds of coal consumed in evaporating 1 lb. of water at 200° F. into steam at 80 lbs. pressure $= 1 \div 8. = .125$.

Pounds of water consumed per H. P., 25 lbs.

Pounds of coal consumed in evaporating 25 lbs. of water at 200° F. into steam at 80 lbs. pressure $= 25 \times .125 = 3.125$ lbs.

Pounds of coal consumed per hour for 100 H. P. $= 100 \times 3.125 =$ 312.5 lbs.

Heat units in pound of fuel, 10,000 H. U.

Heat units contained in all the coal consumed, $10{,}000 \times 312.5 =$ 3,125,000 H. U.

Mechanical equivalent for one H. U., 778 foot pounds.

Foot pounds of work stored in all of the coal consumed each hour $= 778 \times 3{,}125{,}000 = 2{,}431{,}250{,}000$ ft. lbs.

Foot pounds of work done per hour by each I. H. P., $33{,}000 \times 60 =$ 1,980,000 foot pounds.

Foot pounds of work per hour by 100 I. H. P., $1{,}980{,}000 \times 100 =$ 198,000,000 foot pounds.

Losses in overcoming friction of engine, about 10 per cent, 10 % of $198{,}000{,}000 = 19{,}800{,}000$ foot pounds.

Total foot pounds of useful work at the engine shaft per hour, $198{,}000{,}000 - 19{,}800{,}000 = 172{,}000{,}000$ foot pounds.

Foot pounds lost per hour, $2{,}431{,}250{,}000 - 172{,}000{,}000 = 2{,}259{,}250{,}000$ foot pounds.

Percentage of useful work, about 9 2-10 per cent; $2{,}259{,}250{,}000 \div 2{,}431{,}250{,}000 =$

Percentage of lost work, about 90 8-10 per cent.

Engines, Indictaors, Shafting, Belting, Etc.

Q. 5. (1896-7.) Are liners between bearings good practice? Why? How properly adjusted?

Ans. 5. Liners between bearing boxes are good practice. 1st, they will keep dust or grit from getting in the journals, prevent the caps from working loose and prevent rattling of the boxes. 2d. For large engines the weight of the top box and cap would otherwise increase the friction. Liners are adjusted as follows: After the boxes have been carefully fitted, lead wires of suitable thickness are placed between them. The cap is then screwed down hard, thereby flattening the leads. They are taken out and used as a gage to fit the liners, which should be a trifle thicker.

Q. 18. (1896-7.) How much change made in valve travel by turning ¼″ off eccentric [all around].

Ans. 18. None; except that rod length will have to be altered to maintain position of valve.

Q. 31. (1896-7.) What is the proper relation between cylinder and steam pipe areas for automatic cut-off engines?

Ans. 31. Velocity of entering steam should not exceed 8,000 ft. per minute.

$$\text{Area pipe} = \frac{\text{Area of cyl.} \times \text{piston speed}}{\text{Velocity of steam in pipe.}}$$

A constant, 6,000 ft., is much used in later practice.

Examples: For 8,000 ft., area pipe = area piston $\times$ .075. For 6,000 ft. area pipe = area piston $\times$ .10.

Q. 34. (1896-7.) What is meant by angular advance of an engine eccentric?

Ans. 34. If a valve has neither lap nor lead and delivers steam in the usual manner, that is, over or around the ends or outside, the eccentric will stand at an angle of 90° with the crank pin either in advance of the crank if direct connected, or behind the crank if indirect connected. If a valve has lap and it is desired that the valve should open the port for steam at the instant the crank pin moves from the dead center, or if the valve is to have lead, that is, to open for steam when the crank is on the dead center, the eccentric must be advanced on the shaft in the direction in which the engine is to run until the edge of the valve is either in line with the edge of the steam port or until the valve has given the required lead opening, the engine being on the dead center. Therefore, the angle of advance or the angular advance of an eccentric is the angle (beyond ninety degrees) that the eccentric is advanced or pushed around on the shaft to bring

the steam edge of the valve in line with the steam edge of the port, if the valve has lap. Or, if the valve has lead or both lap and lead, it is the angle, the eccentric is advanced (beyond 90°) on the shaft to give an opening for steam, the engine in either case being on the dead center.

Q. 37. (1896-7.) What is meant by angularity of the connecting rod of an engine?

Ans. 37. When the crank pin of an engine stands at any point in its path of motion, except when on the dead center, the connecting rod forms an angle with the line of centers, this is termed the angularity of the connecting rod. The angle thus formed is greatest when the piston is in mid-position.

By the line of centers is meant a straight line drawn from the center of the crank shaft through the center of the cylinder.

The shorter the connecting rod is in proportion to the stroke of the piston, the greater the angularity of the rod. Or the angularity of the connecting rod may be described as the equivalent, but not actual, shortening of the rod by its being deviated from the line of centers, which it is at all times except when the crank pin is on the dead centers.

Q. 38. (1896-7.) Why should an engine be given compression? Name all the reasons.

Ans. 38. Compression is given to an engine—1st. To furnish a cushion or gradually increasing resistance to bring the reciprocating parts of an engine to a stop at the end of the stroke and change the direction of the thrust upon them without shock, which would otherwise follow upon opening the steam valve.

2d. If obtained by early closing of the exhaust valves it fills the clearance spaces with steam that would otherwise go to waste by being blown into the condenser, or to the atmosphere.

3d. It insures quiet and smooth running of the engine, taking up the lost motion, if any, without jar.

4th. It reheats the clearance space in the cylinder [cylinder head and piston] promoting economy by thus lessening the amount of internal condensation, a very important item.

Q. 39. (1896-7.) What is the best practice and most accurate way for setting Corliss valves?

Ans. 39. Take off caps of valve chambers; marks will be found; then set wrist plate so that central line on wrist plate coincides with line on stand; set steam valves with 1-4″ lap for 10″ diameter, and 1-3″ lap for 32″ diameter; for intermediate diameters in proportion. Set exhaust valve 1-16″ lap for 10″ diameter, and 1-8″ for 32″ diameter. Proportion intermediate diameters on non-condensing engines; on condensing engines give nearly double this.

The rods connecting steam valve arms to dash pots should be adjusted by turning wrist plate to extremes of travel and adjusting the rod so that when it is down as far as it will go the steel block will just clear the shoulder of the hook. Hook the engine in with the eccentric loose on shaft, and adjust the eccentric rod so that wrist plate will come to extremes of travel as indicated by lines. Place the engine on dead center, turn eccentric (in direction engine runs) until steam valve shows from 1-32″ to 1-8″ lead, owing to conditions; turn engine over to other dead center and note lead on valve; if not the same, adjust rod from wrist plate to valve.

To adjust rods to cut off from governor: Have wrist plate at one extreme of travel, then adjust rod connecting the opposite cam of

steam valve so that cam will clear the steel tail of the hook about 1-32": turn wrist plate to other extreme and adjust the rod the same way. To equalize the cut-off, block the governor up, then turn engine over and note where cross-head is when valve is tripped; then turn on over until other valve is tripped; if not the same, adjust one or the other until they are the same. Next, start the engine and verify results obtained by an intelligent application of the indicator.

Q. 44. (1896-7.) Is there a gain realized in practice from steam jacketed cylinders? If so, under what general conditions?

Ans. 44. The fact that a gain may be realized by steam jacketing is as well established as statements to the contrary, the economy in any particular case depending upon design and conditions attending their application. The subject is quite too intricate to be treated satisfactorily in an abbreviated manner. Briefly stated, the function of the steam jacket is to diminish initial condensation and more fully maintain the temperature of the expanding steam through the stroke. For this purpose the jacket serves as a medium for conveying from the boiler a reinforcement of heat to the working steam, and the conditions to be observed, both in design and management, are such that will subserve this end. The margin of gain at the best is so small that but a slight defect in design or operation may set up conditions with a tendency just the reverse of those which the use of a jacket implies. The surplus heat stored in superheated steam performs to some extent the functions usually attributed to the jacket, consequently the benefit is less pronounced when such is used within the cylinder proper. The gain is materially greater when the heads as well as the body of the cylinder are steam jacketed. Efficiency is greater for long stroke and varies somewhat with the period of admission. For cylinders in series, compound, etc., the gain is greatest in the high pressure cylinders, since the absorption of heat during the exhaust periods is not lost as is the case of the simple engine. For the best results the design should insure a brisk circulation of "live" steam, taken directly from the boiler through all parts of the jacket, and ample provision must be made for freeing the jacket of air and the water of condensation, the latter to drain back into the boiler.

Q. 51. (1896-7.) What should be the ratio between steam cylinder and air pump capacity for a condensing engine?

Ans. 51. For a jet condensing engine, the single-acting pump should have a capacity of from 1-5 to 1-10 that of the cylinder; a double-acting pump would have 1-8 to 1-16 the cylinder capacity. For surface condensing engine the single-acting pump would have a capacity of 1-10 to 1-18 and a double-acting from 1-15 to 1-25 that of the cylinder. In both cases the proportions depend upon the terminal pressure, increasing with same, and for a jet condenser varies with amount of injection used. These proportions are for pumps making same number of strokes as the engine. If the speed varies from that of main engine the size is so calculated as to give same relative displacement as shown above. When an engine is compounded the volume of the low pressure cylinder alone is considered.

Q. 52. (1896-7.) Is brass or babbitt best for bearings? Elucidate.

Ans. 52. Except in case of bearings where the pressure is excessive, where pounding and jarring is liable to occur, or unusually high speeds are attained, babbitt metal must be given the preference over brass as a material for bearings. Babbitt bearings can be the more easily kept cool and there is less liability of the journal cutting. These advantages

are due to its anti-friction properties and to the fact that on account of its softness it will accommodate itself to any slight irregularities in the surface of the journal, and, should the shaft get slightly out of alignment with the bearings, the metal will yield where the pressure is greatest until there is a uniform bearing surface.

Another advantage is that the wear of the shaft will be less rapid, and when the bearings become worn they can be rebabbitted at a slight expense. To give best results, babbitt metal of the right formula or proportion for the work in view should be selected, as the babbitts are made of all degrees of hardness and consistency. It is our opinion that for all around usefulness there is no bearing metal that will approach babbitt.

Q. 55. (1896-7.) How set the valves on a medium speed, simple, non-condensing, automatic, Buckeye engine?

Ans. 55. Under the conditions of the question it is understood that the regular form of Buckeye engine is meant, and it will be necessary to bear in mind that the eccentric follows the crank instead of leading it, as in the ordinary engine, and that the steam chest is not a steam chest as commonly understood, but is an exhaust chamber or box; that is, the cylinder discharges its exhaust steam into the steam chest and takes its supply of steam through the main valve direct from the steam main. There are two valves to this engine, both of the slide valve type and both flat, and their functions are the same essentially as those of the common slide and riding cut-off. The riding cut-off in this case is placed on the inside of the main valve, which becomes a hollow box or chest through which the steam passes.

The main valve has ports on its face nearest to the cylinder which alternately travel over the usual cylinder ports and then away from same far enough to allow the end of the valve to uncover the cylinder port and allow the steam to be exhausted from the cylinder into the steam chest, thus enveloping the valve and keeping it at all times in a bath of hot steam.

There is a separate eccentric for each valve, one for the main valve fixed to the shaft and the other for the riding valve or cut-off, operated by a loose eccentric, which is thrown by the centrifugal force of a weight or weights around the shaft, or is, in other words, given a variable amount of angular advance.

The main, or box valve, is first set independently of the cut-off by putting the eccentric 90° behind the crank, plumbing the rocker arm and equalizing the compressions just as would be done with the leads on a common slide valve, remembering that the ends of the valve are exhaust edges, and regulate the compression or exhaust and not the steam supply. The matter of equal leads in this engine is not of so much importance.

The valves and cylinder faces are marked to designate the position of their respective ports, which are in themselves invisible from the outside, and the necessary lead is given by advancing the eccentric toward the crank or in the direction the engine will run, and equalized in the usual way.

Thus far the engine is the same as a common slide valve type, except that the steam comes in through the valve and exhausts out of and around it. The ends being exhaust edges, the eccentric follows instead of leading the crank.

Bearing this in mind, there should be no trouble in setting the valve. As to the cut-off, this is another common slide valve, much smaller and lighter than the main valve, and working entirely out of sight and inside of the main valve, being rendered visible only, and then with difficulty, by removing the back plates from the main steam chest and withdrawing the balance plates found therein. This valve is driven from a separate eccentric, fastened, not to the engine shaft, but by

links to the governor wheel or frame, so that it may be revolved to the extent of about 90°. Its normal position when at rest is coincident with the crank of the engine, and is held there by the tension of the springs in the governor. If the eccentric is set in the same direction as the main crank, that is all that is necessary. The governor is then set out about two-thirds of the throw of its arms and blocked, and the valve so adjusted by its rods and stems that, as shown through the sight holes, it is cutting off equally on each end.

It has been assumed that the experimenter is skilled in handling and setting the ordinary slide valve. Adjustments in the case of each of the valves of this engine are made at the ends of the eccentric rods and valve stems, as usual, keeping in mind that the main valve acts just exactly opposite to the manner of an ordinary slide.

Compression is equalized by moving the main valve toward the end of the cylinder showing greatest compression, and similarly the cut-off is equalized in the same manner by moving valve toward end of cylinder showing greatest load. After the cut-off is adjusted and equalized, any adjustment for compression equalization on the main valve had better be made on main eccentric rod and not on valve stem. If made on the latter it will be again necessary to make adjustments for cut-off. It is surmised that the valves and parts have the usual shop marks for guidance and that the governor wheel and its parts are properly placed. The whole of the work should be finally proved and corrected by use of an indicator.

Q. 57. (1896-7.) If we get an initial pressure of 70 lbs. in the cylinder and the compression runs up to 35 lbs., both gage pressure, will the clearance be half filled?

Ans. 57. Yes, and more than half filled. Thus:

$$70 \text{ lbs.} + 15 = 85.$$
$$35 \text{ lbs.} + 15 = 50.$$

$85 \div 2 = 42\frac{1}{2}$ lbs. clearance, 50% filled, or $42.5 \div 85 \times 100 = 50\%$, or ½ filled; hence, under the above conditions, we have $50 \div 85 \times 100 = 58.8\%$, which is more than half filled.

Q. 59. (1896-7.) Will the slide valve cut off the same at both ends of the stroke if it has equal lap and lead?

Ans. 59. If an engine has a connecting rod, no. If crank is turned by yoke and piston rod, yes.

Q. 61. (1896-7.) What are the causes of a belt running to one side of a pulley?

Ans. 61. Shafts carrying pulleys not being parallel; pulleys not in line with each other; one edge of the belt being stretched more than the other; pulleys not crowned correctly; pulleys not being bored or turned true, or belts not cut square before lacing or glueing.

An idler, where used, if not true or properly arranged, may cause a belt to run to one side.

Q. 62. (1896-7.) If a common D slide valve has 1 1-16″ lap and the width of the ports is 15-16″, what will be the valve travel to give full port opening at both ends? Explain how it may be found.

Ans. 62. The valve must travel in each direction from its mid-travel an amount equal to the lap and width of the port, which in this case is the sum of 1 1-16″ and 15-16″, which is 2″, thus making the valve travel 4″. This may be found by the use of a valve model or any of the many valve diagrams in use.

Q. 68. (1896-7.) If an engine is to develop 300 H.P. with 35 lbs. m.e.p. and 600 ft. piston speed per minute, what will be the cylinder diameter? Explain how found.

Ans. 68. Rule for finding the required diameter of cylinder for an engine of any given horse-power, the travel of piston and available pressure being given.

Multiply 33,000 by the number of horse-power; multiply the travel of piston in feet per minute by the available pressure in the cylinder; divide the first product by the second; divide this quotient by the decimal .7854. The square root of this last quotient will be the required diameter of the cylinder. Example:

$$\frac{33000 \times 300 \div (600 \times 35)}{.7854} = 600.$$

$\sqrt{600} = 24.4949''$ diameter required.

Q. 72. (1896-7.) What should be the terminal pressure in a steam cylinder of 40″ stroke, 2½% clearance, cut-off at ¼ stroke, initial pressure 108 lbs. by the gage, making no allowance for leakage, condensation or wire drawing, and assuming 15 lbs. atmospheric pressure?

Ans. 72. The terminal pressure will be in the same proportion to the absolute initial pressure as the volume of the cylinder, plus the clearance at point of cut-off, is to the total cylinder volume plus the clearance.

Stroke 40″ + clearance (2½%) 1″ = 41″.
Cut-off (¼) 10″ + clearance 1″ = 11″.
Total pressure (initial) 108 lbs. + 15 lbs. = 123 lbs.
Thus: P : 123 : : 11 in. : 41 in.

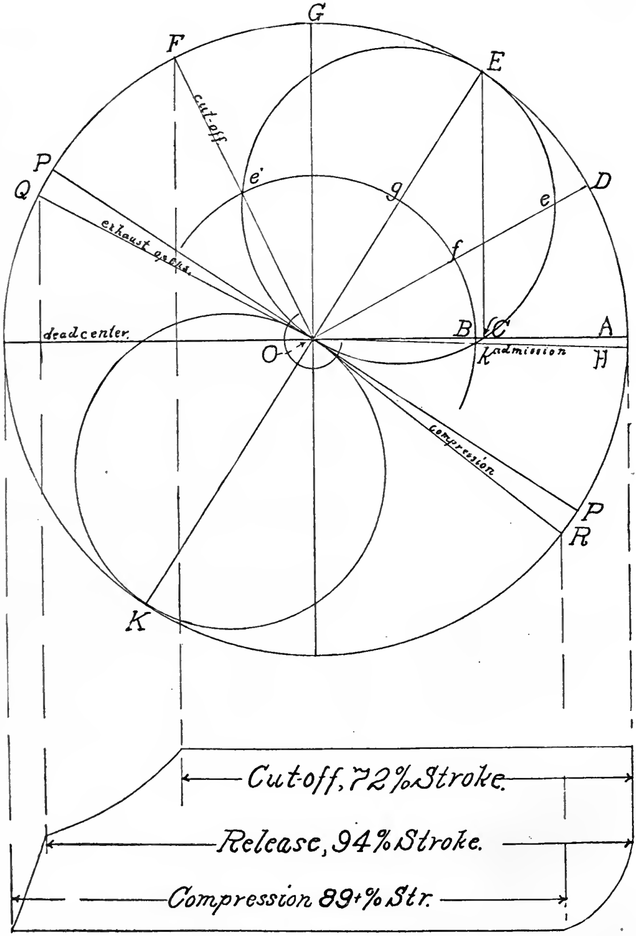
$$\frac{123 \times 11}{41} = 33 \text{ lbs. absolute; the answer.}$$

Q. 73. (1896-7.) What is the distinction between indicated and actual steam consumption of an engine?

Ans. 73. An indicator diagram does not show the actual amount of steam used by an engine for the following reasons:

Leakage of steam often occurs and cylinder condensation is inevitable, yet the extent of these losses is not revealed by any marked effect upon the lines of a diagram.

The measurement of steam consumption by a diagram cannot, therefore, be taken to show actual performance without allowance for these losses, but diagrams taken in connection with feed-water tests will reveal the extent of the losses produced by leakage and cylinder condensation. These losses are represented by that part of the feed water consumption which remains after deducting the steam computed from the diagram, or "accounted for by the indicator," as it is termed. The loss by condensation is nearly constant for different engines working under similar conditions, and an allowance may therefore be made for its amount. The other leakage, depending upon the wearing surfaces of valves, pistons and cylinder, is variable in different cases.



ZEUNER VALVE DIAGRAM

Q. 76. (1896-7.) If an engine is to run 160 revolutions per minute and the governor pulley 256 revolutions per minute, in order to regulate speed of engine, what will be the diameter for governor shaft pulley, if the pulley on engine shaft is 8″ diameter?

Ans. 76. To find diameter of governor shaft pulley:

Rule: Multiply the number of revolutions of the engine by the diameter of the engine shaft pulley and divide the product by the number of revolutions of the governor pulley. Example:

$$\frac{160 \text{ (r.p.m.)} \times 8 \text{ (inches)}}{256 \text{ r.p.m.}} = 5''.$$

Q. 80. (1896-7.) How set the valves on a Porter-Allen simple engine?

Ans. 80. To set the valves of the Porter-Allen engine: There are some distinctive features peculiar to this engine not found in other types that must be considered when setting the valves. The eccentric cannot be shifted on the shaft, as in most other types of engines; it is forged and turned up on the shaft; it is in the same position on the shaft as is the crank, or, in other words, if a line were drawn through the center of the cylinder, crank-pin and shaft, it would also pass through the center of throw of the eccentric. The object of this is to give the valves the same relative fast and slow motion as that of the piston—when the piston moves slow, the valves move likewise, and vice versa.

The valves are four in number—two admission and two exhaust. They are placed on the sides of the cylinder, steam on one side, exhaust on the other. The admission valves are each operated by a separate valve stem. The exhaust valves are both operated by a single stem upon which both valves are mounted. The variable cut-off of the admission valves is obtained by means of a link and block which is connected to the governor in such a manner that it will give a greater or less amount of opening to the valves—the amount depending on the load the engine is to carry, varying from very nearly zero to 56% or 58% of the stroke. The exhaust valves are operated from a fixed point on the link, and are positive in their motion, regardless of the point of cut-off of the admission valves.

From the foregoing explanation it is evident that the adjustment of the valves must be made by changing their relative positions on the stems.

To set the valves, the first thing that should be done is to see that the valve gear is in perfect harmony with the governor connections; this is done by turning the crank to one or the other centers, but not on the dead center. It should be below the center line. A shop mark will be found on the collar of the shaft and another on the corresponding end of the upper box of the pillow block. When these two marks coincide the crank will be at its proper place. Then raise the governor to its highest position and let it down again; if no motion is given to the valves, with the engine in this position, that end is all right. If, however, motion should be given to the valves then the vertical adjustment of the link must be changed until there is no motion to the valves when the link is moved and the crank in this position.

Vertical adjustment of the link is made at the sustaining or supporting pin-boss of the link by means of a key under it and a set screw on top or above it. The construction is such that the boss pin can be raised or lowered as is required. It may so happen that the connecting rod from the link-block to the rocker-arm may have to be lengthened or shortened. To be accurate we should repeat the same operation on the other end. This operation is easily understood by inspection of the engine.

Having found the operation of the link to be right, turn the engine on one dead center and raise the governor to the highest position it will go—this will bring the block between the trunnions of the link. It must be securely blocked and remain in this position while the admission valves are being set. Proceed to set the valves on the same end at which the piston stands (bearing in mind that the valves all move toward the center of the cylinder to open, or in other words, the valve on the head end moves toward the crank end to open, and vice versa), giving it the desired lead which will depend in a great measure on the speed and size of engine, the kind of work being done, the steam pressure and sometimes upon the fancy of the operator. The construction of the valves is such that when they open there are four places through which steam is admitted. The amount of lead is generally from 1/32″ to 1/8″, depending upon the above named conditions. For low pressure cylinders with a condenser the lead is as much as 3/16″, or even more. Next turn the engine on the other center and give the valve the same lead. This being done, move the governor to its lowest position—where it is when the engine is at rest—it will then be seen that the two admission valves have moved toward the crank end of the cylinder. This motion is brought about by moving the block from the trunnions to the extremity of the link (or from one extreme to the other) while the crank stands on dead center. The motion is the same in amount on either center and takes place in the same direction—toward the crank end. The effect is to cover the port nearest the crack and enlarge the opening farthest from it. The lead is equal to the earliest point of cut-off—it is gradually diminished on the crank end and increased at the head end. This is in the same proportion as the steam follows the piston in either stroke. The effect is to equalize the points of cut-off at either end, or it may be said to overcome the distortion produced by the angularity of the connecting rod. If the governor is blocked up at any elevation and the engine turned over it will be found that the openings made and the points of cut-off will be the same for each stroke.

The exhaust valves have a positive motion and are both mounted on one stem, as has been described. To set the exhaust valves make a mark on the guides where it is desired that compression shall take place, or the point where the valve shall close when the piston has nearly completed its stroke. Turn the engine until the crosshead comes to this mark and set the edge of the valve on line with edge of the port so that a slight movement of the crosshead either way will open or close the valve. Turn the engine to the other end and repeat the operation.

The point at which the exhaust port should close is from 2.5″ to 5″ from end of stroke. With condensing engines even more than this is sometimes given, the amount varying somewhat with the speed, etc., but enough must be given to make the engine run quietly.

The exhaust valves can be set while turning the engine to set the admission valves; this will avoid turning the engine so often. The valves are all held in position on the stems by two pairs of nuts which must be securely locked and leave sufficient play so that the valve can adjust itself sideways but at the same time have no end play.

The valves are held in position by what are known as pressure plates. These plates must be sufficiently close to make them steam tight, yet not so tight as to cause unnecessary friction.

If the valve setting has been done by one not thoroughly familiar with this type of engine it should be turned one revolution and the valves and gear carefully inspected to see that all parts move with freedom and accuracy; then put on the steam chest covers, warm the cylinder, start the engine and apply the indicator.

If the indicator diagrams should show that more or less lead is needed on the admission valves the adjustment can be made without removing the steam chest covers by lengthening or shortening the

valve stems as the case may be;—but this cannot be done on the exhaust side, due to the valves being mounted on one stem, unless both valves should require to be moved in the same direction, then the stem could be made longer or shorter without removing the covers.

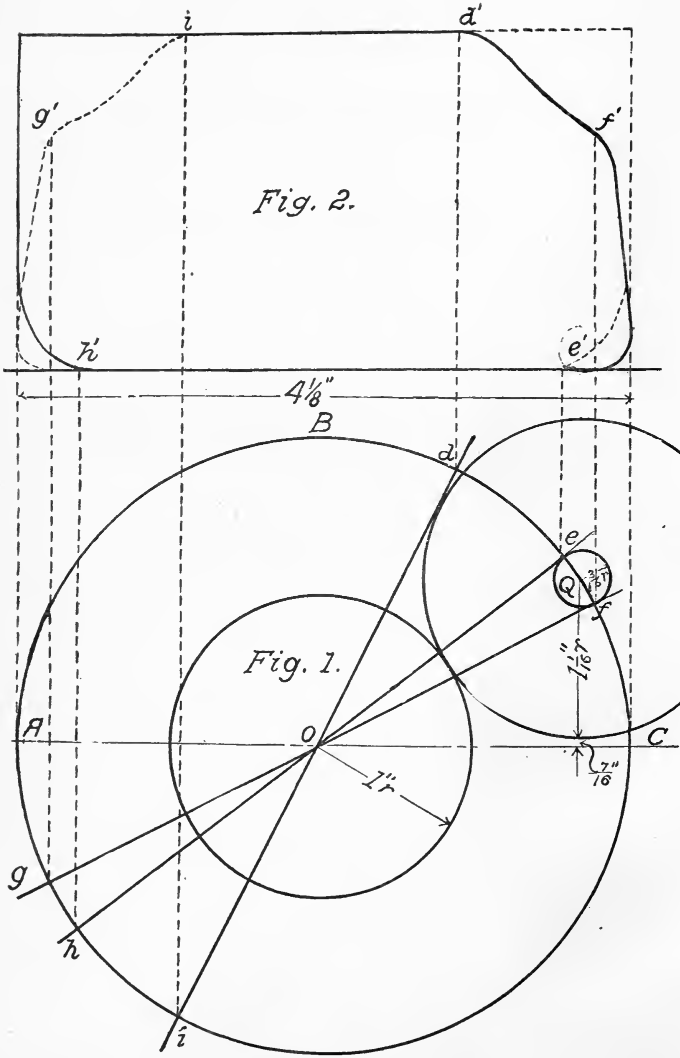
Q. 86. (1896-7.) For ordinary continuous duty, how many r.p.m. would you run a 150 HP simple, Corliss engine? Why?

Ans. 86. We consider the proper size for a Corliss engine to develop 150 HP to be as follows: 16″ × 42″ at 78 r.p.m. 100 lbs. B.P., cut-off 1/5 stroke.

By consulting various builders' catalogues, the rated r.p.m. for this size engine is 75 to 80. This we consider a fair rate. Excellent results, as far as engine performance and steam economy, can be attained at a higher rotative speed, as with 85 or 90 r.p.m., above this the steam lines are not sharp, and the wear upon valve gear becomes very marked; also the silent operation of the engine apparatus is affected. Corliss engines are running nicely at speeds as high as 150 or 180 r.p.m. The reason for keeping the speed down is that the parts, especially the valve mechanism and valves, are more easily kept in repair, a minimum of noise is produced by the engine and dash pots are given time to do effective and perfect work.

Q. 87. (1896-7.) A common D slide valve travels enough to give full port opening, outside lap is 1 1/16″, inside lap is 3/16″ and width of port is 1″, when 1-16″ lead is given, show by a valve diagram the points of cut-off, release and compression, ignoring distortion caused by connecting or eccentric rod.

Ans. 87. Use the Zeuner valve diagram (see diagram) and proceed as follows: Describe a circle, with a radius OA equal to the half travel of the valve. From O measure off OB equal to the outside lap, and BC equal to the lead. When the crank pin occupies the dead center A, the valve has already moved to the right of its central position by the space OB plus BC. From C erect the perpendicular CE and join OE. Then will OE be the position occupied by the line joining the center of the eccentric with the center of the crank-shaft at the commencement of the stroke. On the line OE as diameter describe the circle OCE, then any chords, as Oe, OE, Oé, will represent the spaces traveled by the valve from its central position when the crank-pin occupies respectively the positions opposite to D, E and F. Before the port is opened at all the valve must have moved from its central position by an amount equal to the lap OB. Hence, to obtain the space by which the port is opened, subtract from each of the arcs Oe, OE, etc., a length equal to OB. This is represented graphically by describing from center O a circle with radius equal to the lap OB, then the spaces fe, gE, etc., intercepted between the circumference of the lap-circle Bfé and the valve circle OCE, will give the extent to which the steam-port is opened. At the point k, at which the chord Ok is common to both valve and lap circles, it is evident that the valve has moved to the right by the amount of the lap, and is consequently just on the point of opening the steam-port. Hence the steam is admitted before commencement of the stroke, when the crank occupies the position OH, and while the portion HA of the revolution still remains to be accomplished. When the crank-pin reaches the position A, that is to say, at the commencement of the stroke, the port is already opened by the space OC less OB equals BC, called the lead. From this point forward until the crank occupies the position OE, the port continues open, but when the crank is at OE the valve has reached the furthest limit of its travel to the right, and then commences to return, until when in the position OF the edge of the



BILGRAM VALVE DIAGRAM.

valve just covers the steam-port, as is shown by the chord Oé being again common to both lap and valve circles. Hence when the crank occupies the position OF, the cut-off takes place and the steam commences to expand, and continues to do so until the exhaust opens. When the line joining the centers of the eccentric and crank shaft occupies the position opposite to OG at right angles to the line of dead centers, the crank is in the line OP at right angles to OE, and as OP does not intersect either valve-circle, the valve occupies its central position, and consequently closes the port by the amount of the inside lap. The crank must therefore move through such an angular distance that its line of direction OQ must intercept a chord on the valve circle OK equal in length to the inside lap before the port can be opened to the exhaust. This point is ascertained by drawing a circle from center O with a radius equal to the inside lap; this is the small inner circle in the figure. Where this circle intersects the valve circles we get the points which show the positions of the crank when the exhaust opens and closes. Thus at Q the valve opens the exhaust on the side of the piston which we have been considering, while at R the exhaust closes and compression commences and continues till the fresh steam is admitted at H. To resume the operations: Steam admitted before the commencement of the stroke at H. At the dead center A the valve is already opened by the amount BC equal to 1/16″. At E the port is fully opened, and the valve has reached one end of its travel, or 2 1/16″ from its central position. At F steam is cut off, consequently admission lasted from H to F. At P valve occupies central position, and ports are closed to both steam and exhaust. At Q exhaust opened and expansion lasted from F to Q. At K exhaust opened to maximum extent, and valve reached the other end of its travel. At R exhaust closed, and compression begins and continues till the fresh steam is admitted at H.

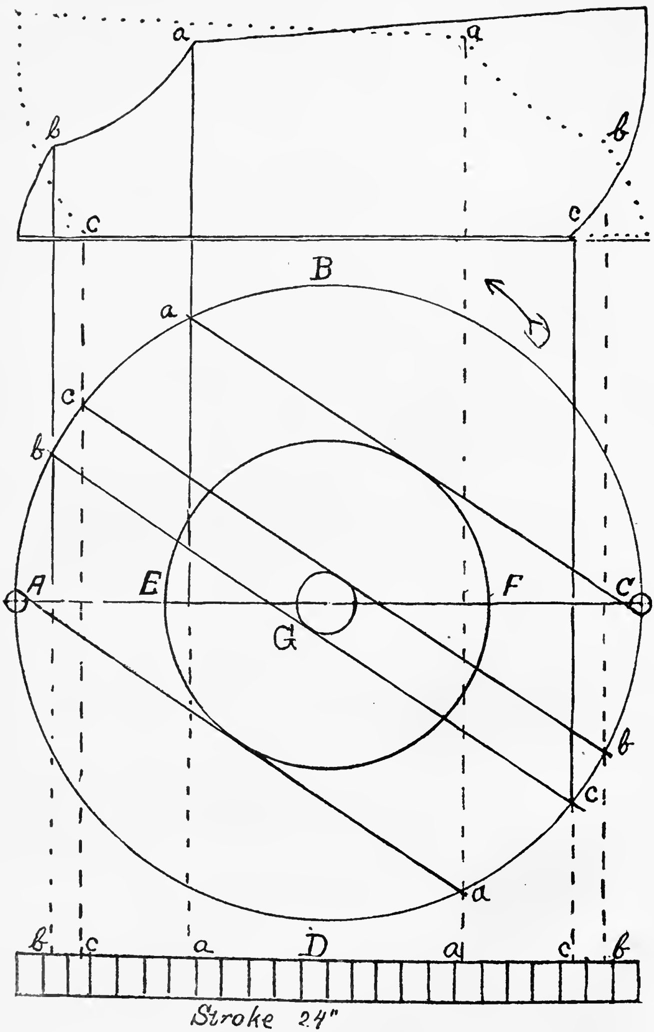
EXPLANATION OF BILGRAM DIAGRAM.

Fig. 1 is the diagram proper; the circle ABC represents the path of the center of the eccentric. The circle of 1″ radius drawn about the center O is the port circle. The large and small circles drawn about center Q represent the steam and exhaust laps respectively; d.h.f. represent the points of cut-off, compression and release for the full line card projected to d′h′f′ in Fig. 2. Also i,e,g represent corresponding points projected to i′,e′,g′, for the dotted line diagram, also shown in Fig. 2.

The dimensioned space marked 1/16″ equals lead of valves. The circle ABC is also used to represent the crank circle to any scale, as the length of the crank is not given. No attempt has been made to draw theoretical curves in Fig. 2, the object of this diagram being a graphic explanation of Fig. 1.

THE SWEET VALVE DIAGRAM—EXPLANATION.

Lay off the horizontal line AC; draw the circle ABCD equal in the diameter to the width of the port and outside lap of valve; this gives the valve travel in full measurement (being in this case 4⅛″); draw the circle EF. This is equal in diameter to twice the width of the outside lap of the valve (in this case 2⅛″). Around the same center draw the circle G, which is equal in diameter to twice the width of the inside lap (in this case ⅜″). Draw the two small circles at A and C equal in diameter to twice the lead (⅛″ in this case). Lay off the line Ca to touch the lead circle and outside lap circle. Where it intersects the valve circle at a, is the point of cut-off. Lay off the two lines bc and cb parallel to Ca, touching on the inside lap circle where these two lines intersect the



SWEET VALVE DIAGRAM.

valve circle at b and c is the point of release and compression, b being release and c compression.

Above the diagram are indicator cards. Below is a scale of 24" stroke, showing theoretically all the points at which the events would take place, by following the heavy and dotted lines and their letters. The theoretical result of the indicator card here given is seldom if ever obtained in actual practice.

Q. 88. How many ropes required to transmit 85 HP at a rope speed of 2,500 ft. per minute, breaking strain of ropes equals 9,000 lbs., working strain 1¼ per cent of the breaking strain?

Ans. 88. Under the conditions imposed the number of ropes required will be ten (10) and may be determined as follows:

Reduce the horse-power to foot pounds, then $33,000 \times 85 = 2,805,000$ ft. lbs., which divided by 2,500 ft. (rope speed) gives 1,122 lbs. as the gross pull on all the ropes; 1¼% of 9,000 lbs., or 112.5 lbs., is the allowable strain for any one rope, and divided into 1,122, the total strain, will give 9.97 +, or say in even numbers 10 ropes.

Q. 92. (1896-7.) Name three remedies for cylinder condensation.

Ans. 92. 1. Compounding.
2. Steam Jacketing.
3. Superheating.

Q. 95. (1896-7.) Are two-cylinder, non-condensing, compound, high speed engines of less than 100 HP economical?

Ans. 95. Tests made by practical engineers have demonstrated that the steam consumption of the type of engine named in the question is not less than 26 lbs. per HP per hour, and very seldom as low as the figure given. The first cost of such an engine is out of proportion to the slight gain in economy. The cost of maintenance, the increased friction and the space required make such an engine undesirable.—Note: Under proper conditions of pressure, speed or load this type of engine may be economical of steam, but it is the solitary exception to a broad, general rule to the contrary.

Q. 96. (1896-7.) What is the maximum allowable pressure per square inch on a crank pin?

Ans. 96. This differs with different authorities, some claiming that the maximum pressure should not exceed 400 lbs. to the square inch of projected area, equal to diameter × length of pin, while others claim as high as 800 to 1,200 lbs., to the square inch. Would consider that for iron pins a pressure of 500 lbs. and for steel 800 lbs. to the inch not excessive, especially as the load is intermittent. It is doubtful whether the pins would stand a constant pressure like that given. Less pressure should be used with high speeds.

Under above conditions lubrication becomes an easy problem.

Q. 98. (1896-7.) How large is the low pressure cylinder of a compound engine as compared with the cylinder of a simple engine doing equal work with the same speed and pressure?

Ans. 98. If the initial and terminal pressures are to be the same, the ratio of expansion must be the same in both cases, and if the work done is equal, then the cylinders must be of the same size. To illustrate: Take case of a simple engine 20″ × 36″, 100 r.p.m., 135 lbs. steam, exhausting at 15 pounds—both absolute. Then, 135 ÷ 15 = 9, or ratio of expansion with back and terminal pressures equal. The m.e.p. will be 32.95 lbs. and the HP 314 × 32.95 × 600 ÷ 33,000 = 187.8.

If a compound is to be used, the low pressure cyl. will be 20 × 36, the ratio for each cylinder will be 3 and the terminal in the high pressure cylinder will be 135 ÷ 3 = 45 lbs. With equal back pressure the m.e.p. will be 49.45 lbs. and the HP 104 × 49.45 × 600 ÷ 33,000 = 93.5. Assuming the initial pressure in low pressure cylinder to be 45, the terminal will be 45 ÷ 3 = 15 and the m.e.p. 16.48; then 314 + 16.48 × 600 ÷ 33,000 = 94 HP.

93.5 + 94 = 187.5 power for compound engine, same as for simple.

Q. 99. (1896-7.) What is the safe rim speed for an 18 ft. cast, split, band-wheel, 5″ thickness of rim, and 36″ face?

Ans. 99. Holmes, pp. 247 and 161, gives:

$$\text{R.P.M.} = \frac{W \times TS \times r \times .00034}{2 \times \pi}$$

W = weight of rim in lbs.
TS = safe strength of iron = 700 lbs.
r = radius = 9 ft.
.00034 = a constant.
π = 3.1416; then substituting
W = 18 × 3.1416 × 12 × 5 × 36 × .2604 = 31807 lbs., and

$$\text{R.P.M.} = \frac{31807 \times 700 \times 9 \times .00034}{6.2832}$$

and R.P.M. = 104 = 97 ft. per second.

If the mean radius, something less than 9 ft., and the mean weight had been used the result would have 2% to 5% less than above.

Theoretically, leaving out of consideration the rigidity of construction, the strength of a wheel, as regards centrifugal force is independent of its weight.

Kent, page 822, says at 5000 ft. per min. an 18 ft. wheel may run 88 R.P.M. and at 6000 ft. per minute may run 105 R.P.M., but does not recommend such high rim speeds for cast iron wheels.

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*Q. 23. (1897-8.) What is the average weight of steam per horse power per hour consumed by—

(a) Automatic cut-off single cylinder non-condensing engines of about 100 HP.

(b) Double expansion condensing engines of about 500 HP., in good practice?

Ans. 23. (a) About 25 to 30. (b) About 12 to 15.

Q. 24. (1897-8.) A single cylinder condensing engine has a terminal pressure of one atmosphere absolute; the work required of it is gradually increased; after a time it is found that the terminal pressure is three atmospheres absolute—what alteration of the engine would you recommend to better adapt it to its work?

Ans. 24. Compound the engine by adding a low pressure cylinder.

Q. 28. (1897-8.) An engine has a twelve (12″) inch stroke. Its connecting rod is three (3) feet long. It is running at six hundred (600) revolutions per minute. The weight of its piston, piston-rod and cross-head is 250 lbs. Draw to scale a diagram such that horizontal distances shall represent piston-positions and vertical distances, piston-velocities at the respective positions, neglecting the angularity of the connecting-rod.

Ans. 28. Lay off horizontally, to a convenient scale, the larger the better, a line A, C, Fig. 2, to represent the stroke of the piston. Draw upon this line a semi-circle A, B, C. Then will points upon the horizontal line represent piston positions and the vertical distances above said points to the semi-circle will represent piston velocities at the corresponding positions of the piston.

The radius B, D, of the semi-circle represents the velocity of the crank-pin, and the vertical lines at other points of the stroke velocities proportional to their lengths.

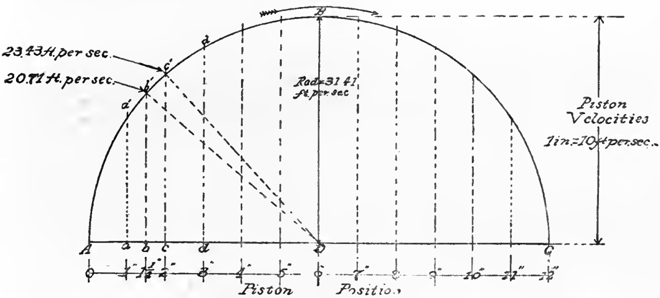


FIG. 2

Q. 29. (1897-8.) In the engine of Q. 28 what is the approximate velocities of the piston at positions one and one-half (1-5″) and two (2″) inches from the commencement of its stroke? Explain how you find this by the diagram of Ans. 28.

Ans. 29. In Fig. 2, the scale is ¼″ to the inch. The radius of the semi-circle is therefore 1.5″. The vertical line b, b, at the point which represents a position 1.5″ from the commencement of the stroke, is .992″ long. The velocity, therefore, at this point is found by the proportion 1.5 : .992 : : 31.4 : answer. By multiplying 31.4 by .992 and dividing by 1.5 we find the velocity at this point to be 20.77 ft. per second.

The vertical line, c, c, at the position corresponding to 2″ from the commencement of the stroke is 1.118″ long. Calculating as above the proportion would be 1.5 : 1.118 : : 31.5 : 23.4 Therefore the velocity at 2″ from the commencement of the stroke is 23.4 ft. per second.

Q. 30. (1897-8.) With the engine of Q. 28 what is the approximate average force due to the inertia of the piston, piston-rod, and cross-head, while the piston is passing from a position one and one-half (1.5″) to a position two (2″) inches from the commencement of its stroke? Solve by the use of the rule of Ans. 27 and the diagram of Ans. 28, and explain fully the method of calculation.

Ans. 30. The weight of the parts is 250 lbs. The velocity at 1.5″ is 20.77 ft. per second. The velocity at 2″ is 23.4 ft. per second. There-

fore, according to the rule of Ans. 27, the work done upon the parts to change their velocity from one value to the other is 250 × [(23.4)² — (20.77)²] ÷ by 64.4, that is 250 × (547.56 — 431.4) ÷ 64.4 = 250 × 116.16 ÷ 64.4 = 541 foot-pounds of work done upon the reciprocating parts to increase their velocity in ½" travel. Now this work divided by the distance will give the average force exerted. Thus 451 foot-pounds of work divided by one twenty-fourth of a foot equals 10,824 lbs. as the average force due to inertia.

The change of angularity of the connecting rod may be taken into account by multiplying the result by one plus the ratio between the crank and connecting rod, that is, in this instance, by one and one-sixth. If the calculation had been made on the latter half of the stroke, the correction would have been made by multiplying by unity, minus the ratio of the crank to the connecting rod; in this instance by 7/6.

Q. 34. (1897-8.) In the engine of Q. 28, if the steam is suddenly shut off while the engine is running at full speed and running over, what force would be necessary to keep the cross-head from pressing against the upper guide when the piston is one inch from the commencement of its forward stroke? Explain method of calculation.

Ans. 34. As the steam is shut off we only have to deal with the forces of inertia. By referring to the diagram Fig. 3, we find that the force at this point, 1" from the commencement of the stroke, is 14,000 lbs. Now draw a line a, b. Fig. 4, to represent the position of the connecting rod. Let the line a, b, represent, by its length, 14,000 lbs., which is the tension upon the rod. Complete the rectangular parallelogram a, b, c, d, then will the line a, c, represent by its length the

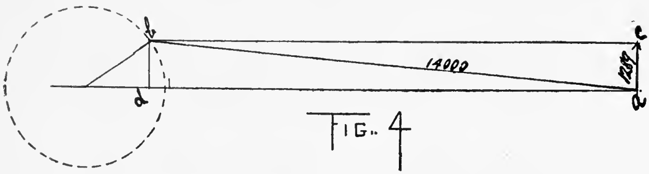


FIG. 4

upward effect of the tension upon the connecting rod. Thus the length of the line a, b, in the figure is 6", the length of the line a, c, is .5527". Therefore, 6 : .5527 : : 14,000 : 1.289. Therefore it would be necessary to exert a downward force of 1,289 lbs. to keep the cross-head from pressing upon the upper guide at this point.

Q. 35. (1897-8.) If the engine of Q. 28 has a cylinder 10" internal diameter and is running with a gage pressure of 70 lbs., what is the greatest strain brought upon the connecting rod? The weight and angularity of the connecting rod, lead, back-pressure and compression being neglected.

Ans. 35. We have the force of inertia and the steam pressure to take into account. By referring to Fig. 3 we find that there is at the commencement of the stroke a tension of about 18,000 lbs. on the connecting rod due to the inertia of the parts; but the action of the steam is to produce a compression upon the connecting rod. That is, at the commencement of the stroke the steam pressure acts in the opposite direction to the force of inertia. Therefore the strain upon the connecting rod at the commencement of the stroke is 18,000 — 70 × 78.54 (area of the 10" piston) = 18,000 — 5498 = 12,502 lbs. tension upon the connecting rod. At the end of the stroke the force of inertia is 15,310

— 2552 = 12,758 — a force of compression; to this should be added the final pressure of the steam upon the piston, if any. Therefore, the greatest strain brought upon the connecting rod is equal to about 12,758 lbs. and steam pressure, if any, and is a force of compression at the end of the stroke.

Q. 36. (1897-8.) Draw, to scale, a diagram of the engine of Q. 28 that shall show the distances traveled by the piston at each angular position of the crank.

Ans. 36. With the compass set to a radius equal (to a convenient scale) to the connecting rod, draw the circle b, c, d, i, l, Fig. 5. Upon the same diameter with the compass set to a radius equal to the length of the connecting rod plus the length of the crank, draw a circle b, e, f, h, k, touching the first circle at b. Draw radial lines a e, a f, a h, from the center a, to the larger circle. Then will the portion of said lines between the two circles be equal to the travel of the piston at the corresponding angular position of the crank. Thus, when the crank is

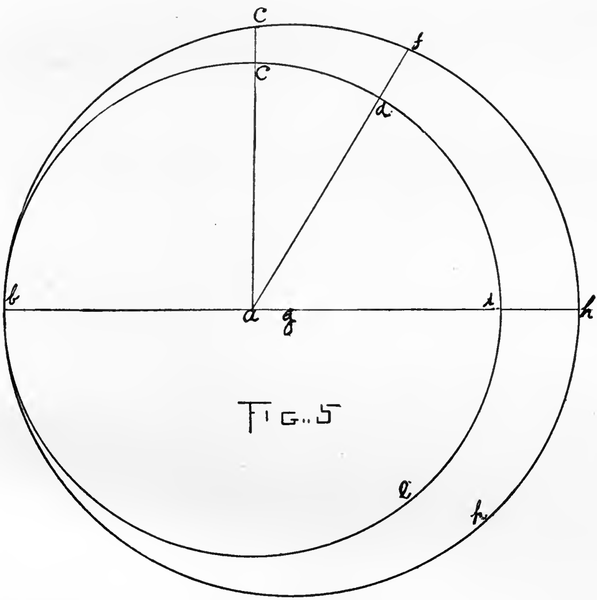


FIG. 5

in the position a, e, the travel of the piston is equal to c, e, measured by the scale adopted, and when the crank is in the position a, f, then d, f, is the travel of the piston from the commencement of the stroke.

If the diagram of Ans. 36 is drawn around the same center as the Zeuner valve diagram, both the valve and piston travel will be shown for each angular position of the crank, by the same diagram.

Q. 37 (1897-8.) What per cent of the steam is condensed by the cylinder walls in simple non-condensing, fast running engines, without steam jackets, of from 50 to 100 HP.?

Ans. 37. From 25 to 50 per cent.

The object of Q. No. 37 is to call attention to the great importance of cylinder condensation. The quantity of steam condensed being much too great to be accounted for by radiation from the outside of the cylinder, and only to be accounted for upon the supposition that much of the heat goes to re-evaporating the condensed steam.

Q. 41. (1897-8.) Does the fly-wheel increase the power of the engine?

Ans. 41. It regulates but does not increase the power.

Q. 51. (1897-8.) What should be the shape in cross-section of the connecting-rod of a fast running engine? Why?

Ans. 51. The cross-section of the connecting rod in fast-running engines should be rectangular and greater in the plane of motion than perpendicular to said plane. In his paper read before the A. S. M. E. Mr. John H. Barr finds as the average of a large number of engines that the depth is 2.7 times the breadth.

The depth is made greater in order to resist the bending action of the inertia of the rod itself.

Q. 52. (1897-8.) Assuming a factor of safety of 20 how would you determine the diameter of a connecting rod having a circular cross-section?

Ans. 52. To calculate the diameter of a circular connecting-rod may be used the following:—

Rule:—Multiply the maximum pressure that may be brought upon the rod, in pounds, by the factor of safety, and extract the fourth root (i. e., the square root of the square root) of this product. Call this result No. 1.

Extract the square root of the length of the connecting-rod expressed in inches. Call this result No. 2.

Multiply result No. 1 by result No. 2 and divide by 61.75. This will give the maximum diameter of the rod in inches.

This rule is expressed algebraically as follows:—

$$d = \frac{\sqrt[4]{PF}\sqrt{L}}{61.75}$$

Suppose we take the following data for example: Area of piston 100 sq. ins. Weight of reciprocating parts 250 lbs. Speed 250 turns per minute. Maximum steam pressure 50 lbs. Stroke 1 ft. Connecting-rod 36″ long; then the greatest pressure of the steam on the piston would be $100 \times 50 = 5000$ lbs. The pressure due to inertia would be about $250 \times 13 \times 13 \div 16 = 2641$ lbs. Therefore the maximum pressure to adapt the rod to is $5000 + 2641 = 7641$ lbs.

Using a factor of safety of 20, we would have, pressure $\times$ factor of safety $= 7641 \times 20 = 152{,}820$. The square root of 152,820 is about 391, and the square root of 391 is about 19.77. Therefore the fourth root of 152,820 is about 19.77. This is result No. 1.

The square root of 36, the length of the connecting-rod, is 6.

Six times 19.77 is 118.62, and this divided by 61.75 is 1.92, say a 2″ circular connecting-rod.

In Mr. Barr's paper, above referred to, the average factor of safety in slow running engines with circular rods was found to have been 13.

In the examples of Ans. 52 and 54, the pressure due to the inertia of the parts is taken into account. In some cases this would be material, in others it would have but little effect. It is in any case easily calculated.

Cylindrical and square parts are so common in machine construction that the rules for calculating their strength are very useful. Such rules are not intended to give exact results, they are intended to tell us when a part is liable to be overloaded, and when it is safe. For this purpose they are reliable.

Q. 53. (1897-8.) How are the dimensions of a connecting-rod having a rectangular cross-section determined?

Ans. 53. The method of securing the ends of the connecting-rod would require that the height (H) of the cross-section should be twice its breadth (B). The inertia of the rod, its whipping action, would require a still greater relative height to breadth.

Mr. Barr found the minimum H to be 2.2 B, the maximum H, 4 B, and the average H to be 2.7 B.

Assuming this average relative value of H, the following may be taken as the

RULE FOR CALCULATING THE DIMENSIONS OF A RECTANGULAR ROD.

First. Multiply the maximum pressure, in pounds, that may be brought upon the connecting-rod, by the factor of safety, and extract the fourth root of the product. That is, get the square root of the square root of this product. Call this result No. 1.

Second. Find the square root of the length of the connecting-rod (expressed in inches). Call this result No. 2.

Third. Multiply result No. 1 by result No. 2 and divide this product by 127.8.

This will give the breadth of the rod in inches. The height is 2.7 times the breadth.

This is expressed algebraically as follows:

$$B = \frac{\sqrt[4]{PF}\sqrt{L}}{127.8}$$

In which, as before, F is the factor of safety, P the maximum pressure that may be brought upon the rod, L the length of the rod in inches, 127.8 is a constant.

Q. 54. (1897-8.) What would be the dimensions of a proper connecting-rod for the engine of Q. 28 assuming a gage pressure of 70 lbs.?

Ans. 54. The pressure due to the inertia of the parts is 12758, the maximum pressure due to the steam would be $78.54 \times 70 = 5498$. Therefore the greatest pressure might be $12758 \div 5498 = 18256$. Assuming a factor of safety of 20 the calculation would be as follows: $20 \times 18256 = 365{,}120$. The square root of 365,120 is about 604 and the square root of 604 is about 24.58. Result No. 1. The length of the connecting-rod is 36″; the square root of this 6: $6 \times 24.58 = 147.48$, and this divided by the constant, 127.8, gives 1.154 as the breadth of the connecting-rod; $2.7 \times 1.154 = 3.1158$ for the height of the cross-section.

Q. 57. (1897-8.) If the pinion to the elevator should be broken, what data would you send to the factory to secure a wheel to replace it? Give specifications.

Ans. 57. Diameter of wheel, diameter of shaft, diametrical pitch, width of face, width and depth of keyway.

PREFACE TO 1898-9 QUESTIONS AND ANSWERS.

"FOUNDATIONS."

The utility of good, firm and lasting foundations under a boiler, engine or other moving mechanism about a steam plant will hardly be questioned, and while some situations are attended with natural advantages favoring this end, it is not infrequently the case that considerable extra labor and forethought are entailed to bring about the desired result.

Examples of poorly constructed and overloaded foundations are abundant and their general effect too well known to require much comment; all that could be said on this subject, however, might be accepted as an apt simile of the difficulties encountered by engineers who endeavor to build "temples" of knowledge upon a substructure inadequate to receive it.

The absurdity of placing a hundred horse-power engine on a ten horse-power foundation is striking, but there is no evident reason why this is not to be considered just as practicable as an effort to acquire the higher branches of engineering science without regard to the fundamental principles which are the natural approach to this greatly coveted goal.

It is not believed that this slight of elementary principles is wholly intentional on the part of many who are seeking to place themselves on a higher plane, hence if a few pertinent suggestions will serve as a beacon to some of our workers the purpose of this article will be fully accomplished.

Solutions of various engineering problems, by means of rules and formulæ, do not afford much satisfaction to the engineer, who is not, in a general way at least, familiar with the process of reasoning upon which the final result depends. By a rigid application of the several operations indicated by the mathematical prescription arranged for him, a proper answer is obtained, but the "spice" of perfect confidence and assurance which should be felt in the work does not attend the result.

To safely use even the most ordinary engineering formulæ it is regarded as essential that a keen knowledge of ordinary arithmetic is at ready command, and further, that the application of its principles to the usual methods of measuring and computing surfaces and volumes has been mastered well. It is equally important that a precise knowledge of the points embraced in a course of natural philosophy should be well founded in an engineer's mind, and while engaged in crowding in knowledge at the "bung" it is well to see that none gets away at the "spigot." Should the conditions just noted be reversed, it is a foregone conclusion that the case is just about as hopeless as when the "cask" is claimed to be so full that it can hold no more.

Among many other things that should be incorporated in an engineer's "foundation" of knowledge, no other is of more value than absolutely correct "notions" concerning the methods of loading a structure and thoroughly understanding the strains induced thereby.

Well fixed ideas of forces and their different effects should be studied, for it is the effect of forces that the engineer has to do with, and if he fails at any time to recognize their existence, and does not succeed in bending them to his will or foretelling their possible action, it is frequently due to the fact that he may not know enough to properly locate them and predetermine results that are to be avoided.

In its broadest sense engineering stands for the acquirement of the knowledge necessary to determine with refined accuracy the results or possible effects due to the action of forces; it makes mankind the master over matter and is a science in which theory, practice and reason are combined for the one grand purpose of furthering the ends of civilization.

It is beyond the scope of this article to do more than merely outline some of the obstacles that seem to hinder the progress of our earnest

plodders, and of these there is probably no one other hindrance as great as the common fault of not grasping broadly the important principles upon which the whole fabric is supported. A perfect mastery of rudiments breeds a sort of intuition, that grows unconsciously and develops the man into the successful engineer.

The elementary principles of mechanics and mathematics should be acquired in a way enabling the engineer to base his investigations on a knowledge of such principles as are actually involved in any given case; he must be able to detect these principles, no matter how "clothed" or disguised, and his reasoning is often more effective for a given purpose than either the eye, the ear or the other senses—all of which, however, must be more or less acute to serve his ends.

The foundation, therefore, need not be particularly ostentatious; rather see that the several courses are of the proper material, thoroughly laid and well cemented. If the original proportions are insufficient to carry the final structure, don't continue to build, but tear it down to the bottom and start again with a broader base and a deeper footing. C. H. F.

INTRODUCTIONS TO QUESTIONS 43 TO 62 (1898-9).

INTRODUCTORY.

The questions under the heading "Practical Steam Engineering," are designed to provoke general discussion at association meetings; the aim has been to arrange them in a way, tending to draw out individual opinions without the need of special preparation on the part of even the more advanced members. No special pains have been taken to evade points upon which engineers differ, and it is not the intention of the committee to allow their own particular preferences to interfere with able arguments advanced on either side of a vexed question.

* * * * * * * * * *

FIRST LIST OF QUESTIONS.

Note.—This embraces some of the principal practical points concerned in the installment of 100 HP engine in an ordinary manufacturing establishment. Answers based on the assumptions indicated in the first question. The answers selected are brief and to the point; the information conveyed will be useful to all engineers who may be new in matters pertaining to such installations.

The committee has added the interlineations which are set out in separate paragraphs, the purpose being to further elucidate the topics, handled in the answers and to point out the line of reasoning followed in arriving at the results.

The comment thus offered in connection with the answers in no way detracts from the worth of the original paper; it proves the figures to be correct and places the work far above the plane of a good guess. It is the "reasoning" that represents the "kernel in the nut."

* * * * * * * * * *

Q. 43. (1898-9.) A simple, non-condensing, automatic engine, with releasing valve-gear is to be chosen, the pressure at boiler is 100 lbs. per square inch and the maximum load is estimated at 100 HP; give bore, stroke and speed of engine you would select to develop this power economically.

Ans. 43. We would select a first-class Corliss engine of "world wide" reputation—size 14″ × 36″, same to run at 80 r.p.m.

(Ed. Com.—Majority of answers favored Corliss engines of 36″ stroke. Cylinder diameters in fractional inches were given by some and though such sizes would, under the assumed conditions, develop the required 100 HP yet, for ordinary purpose, there would be no

greater need for a 13¼″ dia. steam cylinder, than for a 4¼″ dia. pipe; commercial sizes should be adhered to.

Speeds given in the various answers ranged from 75 to 90 revolutions.

Answers to other questions are based on engine dimensions given in Ans. No. 43.)

Q. 44. 1898-9.) Thirty-five feet of overhead pipe, one bend and two elbows are required to convey steam from boiler to engine; 50 feet of exhaust pipe extends to the roof and discharges to atmosphere. Give diameters of both steam and exhaust pipes; state if steam pipe should drain to, or from, boiler and what arrangements are necessary for expansion and other incidental details, also how feed water heater should be provided for, and what is necessary if exhaust steam is to be utilized in heating building.

Ans. 44. Diameter of steam pipe = 4″.

Diameter of exhaust pipe = 5″.

These sizes are taken from well known formulas for steam and exhaust pipes for Corliss engines running under 550 ft. piston speed per minute.

Steam pipe should drain toward engine. As close to the throttle valve as possible should be placed a steam separator of ample capacity, correctly drained and trapped, and of approved design. Steam pipe should be well supported and so arranged as to not tear itself to pieces by expansion and contraction. We prefer all bends made of pipe bent to a long radius for first-class work in lieu of cast fittings of any description. All connections should be flanged.

Exhaust pipe should be led to a heater of ample capacity (we approve of an open heater for this section) and pipe properly drained in low points between engine and heater. The exhaust should be arranged with a proper by-pass, with the necessary valves so that heater can be shut off for cleaning and repairs during operation of engine.

For exhaust heating, a suitable back pressure valve with ample area should be provided.

* * * * * * * * * *

(Ed. Com.—It is generally conceded that velocity of steam should not exceed 6,000 ft. per minute through pipes 100 ft. long. The flow is always assumed to continue throughout the stroke, and with this as a basis we may analyze the given case as follows:

Engine 14″ × 36″, 80 rev.—480 ft. piston speed per min.

$$\frac{\text{Sq. dia. of 14 (cylinder) .....196}}{\text{Sq. dia. of 4 (pipe) ....16}} = 12.25.$$

The quotient represents the ratio of cylinder and steam pipe areas. Piston and velocity of steam will be in like proportion, hence piston speed 480 × 12.25 = 5880 ft. which is "inside" the limit prescribed.

For exhaust pipes a velocity of 4000 ft. is much used; a comparison similar to the above gives for the 5″ pipe specified in the answer—

$$\frac{196 \times 480}{25} = 3763 \text{ feet.}$$

Also within the given limit.

Q. 45. (1898-9.) Give initial pressure and point of "cut off" assumed in connection with your answer to Q. No. 43; also the mean effective pressure corresponding thereto and the probable weight of steam required per hour for each horse-power.

Ans. 45. The initial gage pressure assumed in the answer to Q. No. 43—90 lbs. per sq. in. upon piston.

The point of cut-off for 100 HP at 80 rev. or 480 ft. of piston speed

per minute will equal nearly 22% of the stroke. The mean effective pressure will equal 44 1/2 lbs. for this steam pressure and point of cut-off. These calculations are based upon an assumed clearance of 4% and an absolute back pressure of 16 lbs.

(Ed. Com.—Figures submitted in Ans. No. 45 may be subjected to the following line of reasoning:

$$100 \text{ HP} = 3{,}300{,}000 \text{ ft. lbs.}$$

The distance or space is represented by 480 ft. piston travel per min., hence 3,300,000 ÷ 480 = 6875 is the corresponding "weight to be raised." This "weight" is equally distributed on the face of a 14″ dia. piston; hence the quotient 6875 divided by the area of a 14″ circle = 6875 ÷ 153.9 = 44.6, which is the mean effective pressure necessary for a 100 HP under the specified conditions, and which agrees substantially with the answer.

Point of "cut-off" given at 22% of stroke becomes $36 \times .22 = 7.92$ inches.

The clearance at 4% of the cylinder volume, that is—

$$\text{Area} \times \text{stroke} = \frac{153.9 \times 36 \times .04}{153.9} = 1.44 \text{ in. of stroke.}$$

Ratio of expansion.

$$\frac{\text{Stroke} + \text{clearance} \quad 36 + 1.44 = 37.44}{\text{Cut-off} + \text{clearance} \quad 7.92 + 1.44 = 9.36} = 4.$$

Terminal pressure.

$$\frac{\text{Absolute initial} \quad 90 + 14.7 = 104.7.}{\text{Ratio of expansion} \quad 4} = 26.17.$$

Mean pressure.

Hyperbolic log. ratio of expansion 4 = 1.3863, to which add 1, giving 2.3863.

The terminal pressure $26.17 \times 2.3863 = 62.43$, which is the absolute mean pressure of piston.

The answer assumes 16 lbs. absolute back pressure; hence 62.43 — 16 = 44.43, which is the mean effective gage pressure.

Fixing the initial pressure at 90 lbs. with 100 lbs. at boiler provides for "drop" in pressure between boiler and engine.

Steam required per horse-power is not given. It is safe to assume 30 lbs. per hour for average conditions, although greater economy is possible with such engines.

Q. 46. (1898-9.) The transmission of 100 HP from engine to shaft is by belt; explain the advantages and disadvantages of having main driving pulley distinct from fly wheel. State whether this, or a band wheel, is preferable, provided either could be used.

Ans. 46. This engine is to transmit its power by belt, consequently there can be no valid reason for the use of a separate fly wheel. There may be cases where it is desirable to use a separate band wheel, but this being a new installation it should be arranged without it. Its disadvantages in this particular case would be extra cost and a display of poor engineering judgment.

Q. 47. (1898-9.) The full power of the 100 HP engine referred to, in Question No. 43, is to be belted to a shaft which is to run at 240 revolutions per minute. Give diameters, weight and face of band wheel you would approve of; diameter of first driver pulley and best and most convenient position of engine with reference to shaft.

Ans. 47. A band fly wheel for this engine should be for 80 rev. per min., 10 ft. diam., with a weight of 9,000 lbs. Face should be 20″;

engine running 80 rev., band wheel 10 ft. dia., to drive first driven pulley at 240 rev. we have 10 ft. = 120 ins.; hence

$$\frac{80 \times 120}{240} = 40''.$$

Required diameter of driven pulley.

We prefer to place the engine so it will run "over" and also have the pull of the belt on lower side. * * *

(Ed. Com.—Mr. Stanwood's formula for fly wheel, Corliss engines running at 480 ft. piston speed, is as follows:

$$W = 700{,}000 \times \frac{d^2 \times s}{D^2 \times R^2} = 7717.5$$

W = weight of wheel in pounds.
d = dia. of cylinder in inches.
W s = stroke in inches.
D = dia. of wheel in feet.
R = rev. per min.

According to Thurston's formula the constant number 700,000 becomes 785,400, and applied in that form to the case in hand we have—

$$W = 785{,}400 \times \frac{196 \times 36}{100 \times 6400} = 8659 \text{ lbs.}$$

The answer agreeing substantially with the round number given in reply to the question.

Q. 48. (1898-9.) What width, double leather belt, should be provided to transmit satisfactorily 100 HP according to the condition noted in Q. 47? State what you consider the best method of joining the belt and at what angle should same be run for best results?

Ans. 48. The belt should be oak-tanned stock, short lapped and double; width should be 18 ins.

The best and only A1 method of joining a belt of this size is a carefully lapped and cemented joint.

For best conditions the belt should not be led off from the main shaft at a greater angle than 45° from the horizontal. * * *

(Ed. Com.—When the size of a belt is determined by one of the numerous rules on the subject, it is well to size up the result from practical points of view before finally deciding the question. Liberality in belt proportion is a good investment. The need of extremely tight belts should be avoided.

According to some formulas on the subject, an 18" double belt is quite small for 100 HP; by another rule it is ample, and to choose safely between such extremes is a matter of judgment.

Q. 49. (1898-9.) How wide and how deep should the trench for an engine foundation be excavated, in solid earth, and what modifications would be deemed necessary if the conditions were less favorable?

Ans. 49. The length, depth and width of trench for this engine foundation would depend upon the character of the soil.

The length for good conditions would be approximately 24 ft. Depth, 8 ft., with 12" of concrete before beginning brick work. The width opposite main bearing for outboard bearing will depend upon the distance between main bearing and center of outboard bearing, as varying lengths of shafts require different measurements between bearings, and consequently different brickwork as to width at this place. The width of the "L" part of this trench should approximate 13 ft.

In many places it is found desirable to drive piling and upon that place a proper grillage before ramming in concrete. This will satisfy all but extraordinary conditions.

Q. 50. (1898-9.) Which is the preferable material for an engine foundation—brick or stone, and how should same be laid?

Ans. 50. The best material for engine foundations, all things considered, is good hard-burned brick laid in cement mortar and every course wet down and grouted.

Q. 51. (1898-9.) How should the fly wheel pit be proportioned and built?

Ans. 51. The pit should be proportioned for a reasonable amount of room. The walls should be washed and plastered with first-class cement. Also the bottom should be treated likewise, and should, if possible, be connected to the sewer or its equivalent.

Q. 52. (1898-9.) What precautions are to be observed in making, handling and setting a foundation template?

Ans. 52. In a foundation template the center lines of cylinder and main shaft should be square with each other and all bolt holes very carefully located as per foundation drawing. It should be well braced to preserve its alignment. It should be handled with care. It should be set at the proper height and carefully leveled, and also lined to existing lines, if any have been run, and properly made secure to preserve its correct position.

Q. 53. (1898-9.) Explain how foundation bolts should be set and walled up. Describe also the form of fastening preferred for lower ends of same.

Ans. 53. Foundation bolts should be placed in template holes for their reception, the tops raised to their proper heights and the bolts plumbed vertically. Timbers should be slid over the bolts with room enough for plenty of lateral play. The lower ends are best made secure by nuts placed in "pocket plates." Recesses should be placed in bottom of foundation so that these can always be reached. The bottom threads should be long and the point of bolt well leveled, so in case of necessity they can easily be screwed in from top of foundation.

Q. 54. (1898-9.) Would you use artificial or natural stone for coping or capstone? What advantage has one over the other in engine foundations?

Ans. 54. There is but very little advantage of one over the other, providing the artificial stone is properly made. It usually resolves itself into a question of cost and facilities at hand for procuring a natural stone. Whichever are used, they should be always painted to exclude any oil.

Q. 55. (1898-9.) Which are the best for leveling up preparatory to bedding—iron or wood wedges? What precautions are to be observed in this operation?

Ans. 55. Iron wedges are better than wooden ones for this work. It depends much more upon the ability of the erecting engineer than upon the material that the wedges are made of. Many men, erecting engines, lack judgment in driving wedges of all kinds.

In driving wedges it is necessary that they be of the same uniform taper; that they are placed in correct positions under the several parts of the frame, and that they be most carefully driven so as to produce no distortion.

Q. 56. (1898-9.) Explain how to bed the 100 HP engine assumed in Q. No. 43, noting the materials you believe best adapted for the purpose.

Ans. 56. The engine must be placed upon the foundation, carefully lined up and leveled up on wedges. A space of about 5/16″ or so should be left between foundation stones and bottom of frame. This space should be filled in solidly with a thin grouting of 2 parts best Portland cement to 1 part of sharp sand. If the engine has a girder bed with a center bearing under front end of girds, this should be left until the last before grouting. After joint has hardened thoroughly the wedges should be backed out, all joints pointed and trimmed and the joint well painted to exclude all oil.

Q. 57. (1898-9.) How would you treat the foundation and the setting of the outboard bearing?

Ans. 57. The outboard bearing should receive the same careful attention both as to material and care in bedding and should be square with center line of engine and lie in the same horizontal plane.

Before starting the shaft should be rolled over in its bearings by hand and then raised and the babbit linings scraped to a good fair bearing.

Q. 58. (1898-9.) What two tests can readily be applied to an ordinary spirit level to prove its fitness for use in lining up an engine?

Ans. 58. A spirit level can be tested for truth by the usual method of reversing ends and noting position of bubble or by the rather unusual method of an accurate square and plumb bob.

The following from "Instruction to Engineers," issued by the Buckeye Engine Company, is of interest in this connection:

"Good spirit levels will be needed for this work—better ones than can usually be had at the stores—one iron-bodied one in particular, 3″ to 6″ long, to be applied crosswise on slides and elsewhere.

"The test of a good level is the distance its bubble travels for a given amount of departure from the true level. To test a level place it on a planed strip of board or plank two feet long (if the level itself is not a two-foot wooden one); support the ends of the strip on blocks close to ends, so adjusted that the bubble will be in center. Then lift one end and insert a piece of postal card or other card of about the same thickness (a postal card is full 1-100″ thick) and note how much the bubble has moved. It should have moved quite perceptibly; if about 1/8″, and same whichever end is raised, it is very good, if 1/16″, fairly good, but requires very close observation."

Q. 59. (1898-9.) What methods or devices would you use in lining up the crank-shaft?

Ans. 59. For this work we would use a fine waterproof silk line for drawing through center of cylinder and girder and extend it beyond main bearing a convenient distance. Bring the crank-pin up to the line in nearly extreme forward and backward positions; when the distance from line to face of crank-pin hub measures alike when crank-pin is brought up to the line in the two different positions, the shaft is square laterally. A spirit level can be used to adjust shaft in the other direction to the best advantage in this particular case.

Q. 60. (1898-9.) Outline briefly the successive steps and precautions to be observed before a newly-placed engine is ready for steam?

Ans. 60. Before connecting to engine permanently, a new steam pipe should be thoroughly blown out with steam of good pressure. The steam chamber, valve ports, valves, piston, etc., should be carefully cleaned of all foreign matter and liberally supplied with good cylinder oil; also a

generous application of flake graphite. The striking points of piston and also clearance of same should be determined and properly marked. Valve stems and piston should be properly packed. The valves should be properly set. Everything should be made secure and the bearings properly adjusted. The engine should be turned over by hand one complete revolution and moving parts carefully watched for interference and fouling, one part with another. Gradually warm up cylinder and start cylinder lubricator and adjust all oil cups for a liberal supply of oil at first.

After engine has run long enough, say three or four days, always apply indicator and make final adjustments to valves.

Q. 61. (1898-9.) Indicator cards taken prove the engine to underloaded and likely to remain so for some time to come—what course would you pursue?

Ans. 61. First reduce steam pressure. Second, reduce speed if the character of the load as regards regulation will admit of it. Third, in extreme cases it may be necessary to reduce both.

Q. 62. (1898-9.) Give an approximate, itemized estimate, covering the cost of the outfit outlined in the preceding questions, freights, cartage or extraordinary conditions not to be considered.

Ans. 62. The following estimate is based upon A1 material and work:

14″ × 36″ Corliss engine complete	$1,600
Foundation complete, cap and bottom stones	450
Piping complete, including separator, 4″	200
Total	$2,250

(The lowest estimate received was $1,762. The highest was $3,539.75, and includes an indicator outfit and all incidentals. The average of all estimates is $2,233.

The asking for estimates seemed an innovation, yet it is proper that men should have some sort of a notion of the actual money value of the apparatus in their care. A discussion of the "cost of things" is a topic worthy of consideration.—Ed. Com.)

Q. 67. (1898-9.) Steam pressure at boilers is 100 pounds; give bore, stroke and revolutions per minute for a 100 HP high-speed, simple and direct connected automatic engine, suitable for work of the character indicated in Q. 65; the power to be developed within the economical range of the engine, all general conditions assumed to be favorable.

Ans. 67. For 100 lbs. steam pressure at boilers the following proportions are deemed suitable for 100 HP engine of the "high-speed" type referred to in the question.

Diameter of cylinder, 12″; stroke of piston, 12″. Revolutions per minute, 300. Piston travels 600 ft. per minute.

Average mean effective pressure for 100 indicated HP = 49 lbs.

Q. 68. (1898-9.) Why are "high-speed" engines of the type referred to in Q. 67 considered well adapted for electrical installations of the size noted in the preceding question?

Ans. 68. High speed engines of the type referred to in Q. 67 require less floor space per horse-power and are better adapted for direct connection to dynamo; they afford better regulation and, by a higher speed of rotation, effect a saving and a resultant smaller size.

Q. 69. (1898-9.) What are the relative advantages of horizontal and vertical engines and what reasons govern your selection, assuming "make-up" of both types to be about the same?

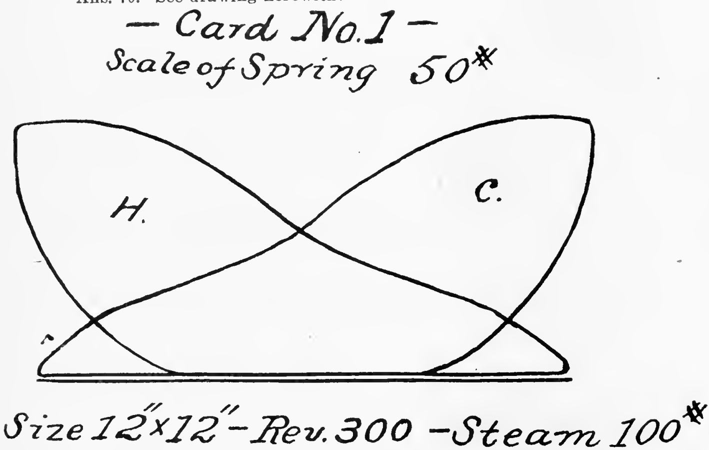
Ans. 69. Assuming the "make-up" of horizontal and vertical engines to be about the same the only advantage the former have over the other is in the matter of head room or height.

In favor of the vertical engine may be noted: Economy of floor space and the fact that piston and valves are less affected by friction and unequal wear and therefore require less lubrication.

It is largely a question of location and the ground room at command; better accessibility of the working parts is a point argued in favor of the horizontal engine. For very large engines the tendency of modern practice is decidedly towards vertical engines.

Q. 70. (1898-9.) Submit sketch, showing by indicator card, the conditions you expect to realize in the cylinder of the engine selected when driving the normal load indicated by Q. 67.

Ans. 70. See drawing herewith:



ANSWER No. 70.

Q. 71. (1898-9.) Under the conditions noted in Q. 70, what will be the probable steam consumption in pounds, per hour, for each horse-power? State also how this compares in economy with the ordinary, well-made, throttling slide-valve engine, performing a like duty?

Ans. 71. Under conditions noted in question 70 the best type of single-valve, simple, non-condensing engine, should produce an indicated horse-power on 32 lbs. of steam per hour.

The excess above figure quoted, depends on losses due to conditions of valves, etc.

For throttle governed slide valve engine cutting off 5/8 stroke, 40 lbs. is usually allotted, although a less amount is claimed for such engines when in good condition.

Q. 72. (1898-9.) Has a "cross-compound," slide-valve engine, fitted with throttling governor, any special advantages for the work outlined in the preceding questions?

Ans. 72. There are many advantages of a cross-compound, throttling engine over a single valve, automatic engine. They are very simple,

show a good economy of steam and maintain this economy over a wide range of power and can be kept free from leakage.

(Ed. Com.—The foregoing is one response favoring the type of engine referred to. Some correspondents would not allow any advantages—answering simply "none." For the work outlined in the question the throttle governed cross-compound would probably be equally as economical; it is questionable, however, if regulation would be as good as in a first-class automatic engine.)

Q. 64. (1899-1900.) If a steam jacket is used, is the steam in the cylinder affected by the heat of the steam in the jacket? If so, explain how.

Ans. 64. It is assumed that the steam in the cylinder, while expanding, receives just enough heat from the steam in the jacket to prevent any appreciable part of it from condensing, without superheating the steam in the cylinder, reducing the condensation in the cylinder to a minimum, the maximum condensation taking place in the jacket. In reference to advantages and economy, see "Kent," page 787, and other noted authors on the subject.

Q. 66. (1899-1900.) Is there any gain in using steam at 100 lbs. gauge pressure, expansively, with a mean effective pressure (M.E.P.) of 70 lbs., over using steam at 70 lbs. the whole length of the cylinder? For illustration, assume a cylinder with a volume of 3 cu. ft.

Ans. 66. Yes, there is a gain in using steam expansively in the conditions as stated by the question.

Using a cylinder with a volume of 3 cu. ft. and an initial pressure of 70 lbs., continued throughout the full stroke, would be using 3 cu. ft. of steam at 70 lbs. pressure, or a weight of .603 lbs. of steam.

If the initial pressure is raised to 100 lbs., and with a M.E.P. of 70 lbs., the cut-off would take place at ⅜ of the stroke; therefore at this pressure there would be ⅜ of 3 cu. ft. of steam used to fill the required volume of the cylinder.

The weight of steam at 100 lbs. pressure equals .264 lb. per cu. ft.

⅜ of .264 lbs. $=$ .099 lb. used for 1 cu. ft. of the cylinder; $.099 \times 3 = .297$ lb. $=$ the proportional quantity of steam used in a cylinder with a volume of 3 cu. ft. Therefore, .603 lb. steam used at 70 lbs. pressure — .297 lb. steam used at 100 lbs. pressure $=$ the amount of steam gained in weight by working the steam expansively at each stroke, or one-half revolution.

$.603 - .297 = .306$ lb., an approximate gain of 51 %, $.306 \div .603$.

Second answer (using the same conditions).

Taking a cylinder of a volume of 3 cu. ft., we will assume a piston area of 1 sq. ft., or 144 sq. in. Discarding clearance, we will only consider as a back pressure that of the atmosphere—viz., 14.7 lbs. per sq. in.—and using the steam expansively with the initial pressure of 100 lbs.; 70 lbs. M.E.P.

One-third cut-off, theoretically, gives for 100 lbs. g.p. 69.96 lbs. M.E.P.; practically, 70 lbs.

In practice it is customary to deduct at least 4 lbs. from the theoretical M.E.P., making it to conform to that determined from actual practice; making the cut-off ⅜ of the stroke, gives, theoretically, 74 lbs. M.E.P.; deducting 4 lbs. gives us the 70 lbs. M.E.P. required.

Hence we have—

Stroke $=$ 3 ft.; 144 sq. in. piston area.

Cut-off $=$ ⅜ stroke $=$ 13½ in., or 1.125 ft.

Initial pressure $=$ 100 lbs. g.p.

Back pressure $=$ 14 7-10 lbs., or atmosphere.

Then $3' \div 1.125' = 2.4 =$ ratio of expansion.

Hgp. Log. $+ 1$ of the ratio of expansion $= 1.8755$; then

$1.8755 \times 100 \times 144 = 27007.2$ foot pounds, the total work done on piston for one stroke.

The negative work, or back pressure, expressed ir foot pounds, equals

$14.7 \times 3 \times 144 = 6350.4$ foot pounds.

27007.2 lbs. — 6350.4 = 20656.8 foot pounds, or the net work done on the piston at 100 lbs. g.p. used expansively, with 70 lbs. M.E.P. for one stroke.

Taking the other condition, using steam at 70 lbs. g.p., the whole length of cylinder, at a constant pressure, we have

$144 \times 70 \times 3 = 30240$ foot pounds, as to the total work done on the piston.

As the negative work will be the same as in the preceding conditions.

$30240 - 6350.4 = 23889.6$ foot pounds of work done on the piston per stroke.

The difference between the two conditions will be $23889.6 - 20656.8 = 3232.8$ foot pounds more work done at a constant pressure of 70 lbs. than when using the steam expansively at 70 M.E.P.

But in using the steam at a constant pressure of 70 lbs. we have used 3 cu. ft. of steam, at a weight of .1971 lb. per cu. ft.; $.1971 \times 3 = .5913$ lb. steam per one stroke.

At 100 lbs. g.p., ⅜ cut-off.

The steam weighs .2617 lb. per cu. ft.; hence

$.2617 \times 1.125 = .2944$ lb. steam used expansively.

Therefore,

$.5913 - .2944 = .2969$ lb. of steam used at a pressure of 70 lbs. constant, doing 3232.8 foot pounds more work than when used expansively at 100 lbs. initial pressure proportionally.

The amount of steam used in the two conditions =

$$.5913 : .2944 :: 100 : x.$$
$$x = 49\ 8\text{-}10\ \%.$$

The percentage gained in using the steam expansively =

$$.5913 : .2969 :: 100 : x.$$
$$x = 50\ 2\text{-}10\ \%\ \text{gained.}$$

Note—Should this example be worked out, on the theoretical basis of ⅓ cut-off, the percentage gained = 55 7-10%.

Q. 87. (1899-1900.) What will be the centrifugal force developed by a fly-wheel eighteen feet in diameter, thickness of rim five inches, width of face forty-three inches, turning at a rate of 90 R.P.M. (the arms and hub not taken into account)? The weight of a cubic inch of cast iron taken as .261 pounds.

Ans. 87. Centrifugal Force:—When a body moves in a circular path it tends at each point to move in a tangent to the circle at that point. But at each point it is deflected from the tangent by a force acting toward the center of the circle. This force may be the tension of a string or the arm of a fly-wheel, or the attraction between a planet and its moon, or the inward pressure of the rails on a curve, etc.

Like all force, it is an action between two bodies, tending either to separate them or to draw them closer together, and acting equally upon both. In the case of a string it pulls the body towards the center, and the hand towards the body, i. e., from the center. In the case of the car on a curve it pushes the car toward the center and the rails from the center.

The push or pull on the revolving body toward the center is called the centripetal force; while the pull or push tending to move the deflecting body from the center is called the centrifugal force.

These two forces, being merely the two "sides" (as it were) of the same stress, are necessarily equal, and opposite, and can only exist together.

The moment the stress or tension exceeds the strength (or inherent cohesive force) of the string, or substance the latter breaks. The centripetal and centrifugal forces therefore instantly cease; and the body no longer disturbed by a deflecting force, moves on, at a uniform velocity in a tangent to its circular path, or at right angles to the direction which the centrifugal force had at the moment it ceased.

The total centrifugal force exerted or developed in a fly-wheel 18 ft. diameter, 43 in. face, 5 in. thickness of rim, is found by the following rule:

Rule:—Multiply the weight of the rim in pounds by the velocity in feet per second, squared; divide this product by tl ɘ value of "g" (32.2′) multiplied by the mean radius in feet.

Expressed in formula:

$$F = \frac{Wv^2}{gR}$$

Let $F =$ total cent. force.
Let $W =$ weight of rim in lbs.
Let $R =$ mean rad. in feet.
Let $v =$ veloc. in ft. per sec.
Let $g =$ rate of accel. in ft. per sec.
Let $r =$ R. P. M.
Let $D =$ mean. dia. in inches.
Let $\pi = 3.1416$.

$$W = D\pi\ (43 \times 5 \times .261)$$

$$W = 211 \times 3.1416 \times 43 \times 5 \times .261 = 37197.5 \text{ lbs.}$$

$$R = 9' - 2\tfrac{1}{2}'' = 8.79'$$

$$V = \frac{2\pi R\,r}{60}$$

$$V = \frac{2 \times 3.1416 \times 8.79 \times 90}{60} = 82.844 \text{ ft.}$$

According to our formula—

$$F = \frac{Wv^2}{gR}$$

$$F = \frac{37197.5 \times 82.844^2}{32.2 \times 8.79} = \frac{37197.5 \times 6863.13}{32.2 \times 8.79}$$

$$F = \frac{255291278.175}{283.038} = 901968. \text{ pounds.}$$

$F = 901968$ lbs.. the total centrifugal force developed by the fly-wheel.

By another formula—using same value of letters—

$$F = \frac{4\,W\pi R\,r^2}{3600\,g} = 902000 \text{ lbs.}$$

A variation of only 32 lbs. between the results of two formulas, probably caused in disuse of decimals.

By another formula using same value of letters—

$$F = .000341\ W\ R\ r^2 = 902016 \text{ lbs.}$$

A variation of only 16 lbs. from second formula.

A variation of 48 lbs. from first formula.

Q. 88. (1899-1900.) What factors enter into the transmitting capacity of leather belts? How is the transmitting capacity calculated?

Ans. 88. Belts and Belting:—Although there is not nearly as much known in general about the power of transmitting agencies as there should be, still it seems that almost any other method or means is better understood than belts.

One of the chief difficulties in the way of a better understanding, or knowledge, of the belting problem is the relation that the belts and pulleys bear to each other. The general supposition, and one that leads to many errors, is that the larger in diameter a pulley is the greater its holding capacity—the belt will not slip so easily is the belief. But it is merely a belief, and has nothing to sustain it unless it be faith, and faith without works is an uncertain factor. The following immutable principles, or laws, should be impressed upon the minds of all interested in this subject:

First—The adhesion of the belt to the pulley is the same—the arc or the number of degrees of contact, aggregate tension or weight of the belt being the same—without reference to the width of the belt or diameter of the pulley.

Second—A belt will slip just as readily on a pulley 4 feet in diameter as it will on a pulley 2 feet in diameter, provided the condition of the faces of the pulleys, the arc of contact, the tension and the number of feet the belt travels per minute, are the same in both cases.

Third—A belt of a given width, making two thousand or any other given number of feet per minute, will transmit as much power running on pulleys two feet in diameter as it will on pulleys four feet in diameter, provided the arc of contact, tension, speed and condition of pulley faces all be the same in both cases, hence—

The principal factors entering into the transmitting capacity of belts are the speed in feet per minute, arc of contact, the position in which it travels, the thickness, weight and the condition of the belt, to adhere to the face of the pulley.

The transmitting capacity of belts is calculated by the following rule:

Allowing 1 inch in width traveling at a given speed in feet per minute to transmit a HP, or by dividing the number of square inches of belt in contact with the pulley, by two (2), multiplying this quotient obtained by the velocity of the belt in feet per minute; divide this product by 33000 and the quotient will be the HP the belt will transmit.

Q. 89. (1899-1900.) Theoretically, what width of belt would be required to transmit 500 HP, with driving pulley 22 feet in diameter, turning 76 R.P.M., size of driven pulley 9 feet, the belt to be of leather, two-ply? From a practical knowledge of belts, what width would you recommend?

Ans. 89. Velocity in feet per minute equals—

$22 \times 3.1416 \times 76 = 5252.75$ feet.

$5252.75 \div 600 = 8.754$ HP per 1 inch of belt.

$500 \div 8{,}754 = 57$ inches, the width of belt required under the conditions of the question for the transmission of 500 HP.

By different rules or formulas the width may be calculated from 50 to 60 inches, but under good practical conditions and circumstances a belt 57 inches in width will be ample in all respects.

There is no doubt whatever that a belt 50 inches will do the required work without trouble if properly cared for.

It is the committee's opinion that ample width in belting is more economical than working too close to the width that will actually perform the work, both in care of and durability of the belt.

Q. 90. (1899-1900.) What is the effective pull of a 30 in. two-ply leather belt, transmitting 300 HP, size of drive pully 20 ft. dia., turning 90 R.P.M.?

Ans. 90. The velocity in feet per minute equals $90 \times 20 \times 3.1416 — 5654.88$ feet.

Then—

$$\frac{300 \times 33000}{5654.86} = 1750.7 \text{ lbs.},$$ the effective pull upon the belt under conditions stated in the question.

The effective pull per 1 inch of width of the belt equal $1750.7 \div 30 = 58.356$ pounds.

Rule:—Reduce the horse-power to foot pounds and divide the number of foot pounds by the velocity of the belt in feet per minute and the result will be the effective pull upon the belt in pounds.

Q. 95. (1899-1900.) At what point in the stroke of an engine is the pressure the greatest on the guides?

Ans. 95. With a uniform pressure upon the piston, the maximum thrust upon the guides will occur when the cranks are at right angles to the axis of the cylinder, or at an angle of 90°.

A drop in pressure, due to an early cut-off or other causes, would modify this statement somewhat, depending upon the point of cut-off, and the angularity of the rod. The maximum thrust upon the guides might occur at a point earlier in the stroke, or before the crank had reached its greatest angle.

By referring to sketch, the triangle DEF represents the crank at an angle of 90°.

The indicator diagram, drawn to represent an initial pressure of 100 pounds absolute scale, 60 pounds per inch in height, with a 25 per cent of the length of the stroke, cut-off, shows that when the piston has reached the point E, representing 50 per cent or one-half stroke, and the crank at 90°, the pressure has fallen to about 48 pounds absolute. Consequently the maximum pressure will take place at a point in the stroke before the crank has reached the angle of 90° to the axle of the cylinder.

Expressed in proportion DE : DF : : horizontal thrust : the downward thrust on guides. Horizontal thrust equals area of piston multiplied by steam pressure.

The distance DE is found by the rules of finding the sides of a right angle triangle, hence—

DE = the sq. root of the difference of the squares of the height on the hypothenuse.

Assuming DF to equal I, the ratio of the length of the crank to the connecting rod = EF.

$$DE = \sqrt{EF^2 - DF^2}$$

when the maximum thrust on the guide at E equals—

$$\frac{DF. \times \text{horizontal thrust}}{DE.}$$

(See sketch.)

Q. 96. (1899-1900.) What will be the greatest thrust on the guides (due to the steam pressure) of an engine 24"x60", having a connecting rod 5½ times the length of the crank, with an unbalanced pressure of 50 lbs. per square inch (gage) on the acting, or working, side of the piston?

Ans. 96. Engine 24" × 60".

Area of piston $= 24^2 \times .7854 = 452.39$ sq. in.

Horizontal thrust parallel with the axis of the cylinder $= 452.39 \times 50 = 22619.50$ pounds.

Length of crank $= 60 \div 2 = 30$ inches, or 2.5 feet.

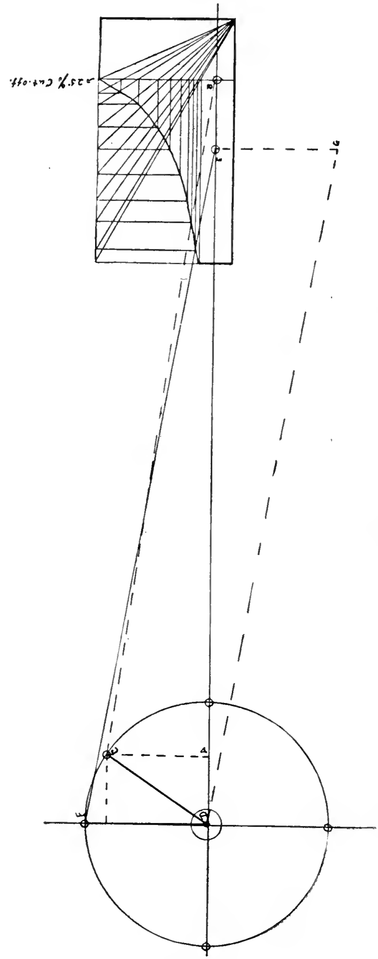
Length of connecting rod equals $2.5 \times 5.5 = 13.75$ feet.

Referring to sketch, question 95.

The altitude DF of the triangle DEF equals 2.5 feet; the hypothenuse EF equals 13.75 feet. The base DE equals

$$\sqrt{EF^2 - DF^2} = \sqrt{13.75^2 - 6.25^2} = \sqrt{182.8125} = 13.52 + \text{ feet,}$$

or length of the base DE; therefore



PRESSURE ON GUIDES. (SEE QUESTION 95.)

$$\frac{2.5 \times 22619.50}{13.52} = 4182.6 \text{ pounds}$$

or downward thrust on the guides.

Q. 97. (1899-1900.) With a guide $5\frac{1}{2}''$ wide and shoe of cross-head 18″ long, what is the greatest thrust on the shoe, per square inch? Taking the same conditions as stated in question 96.

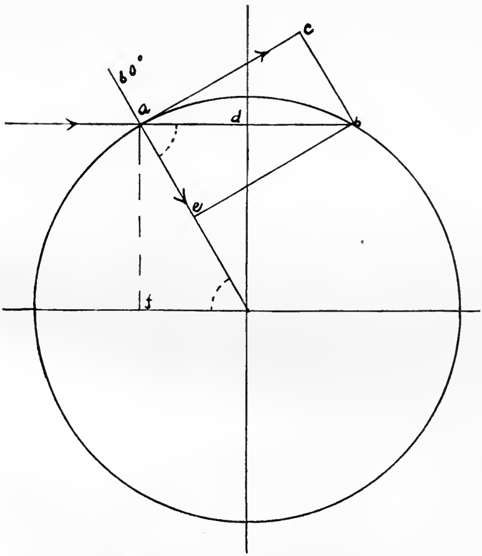
Ans. 97. The superficial area of shoe equals 18 inches $\times$ $5\frac{1}{2}$ inches $=$ 99 sq. in.

As found in Question 96, the total thrust upon the guides is 4182.6 pounds. Then the total thrust per sq. inch equals $4182.6 \div 99 = 42.2$ pounds.

Q. 98. (1899-1900.) In comparison, how do the lengths of connectings rods affect the thrust or pressure upon the guides?

Ans. 98. In comparison the thrust, or pressure exerted upon the guides is affected inversely, as the length of the rods; that is, the longer the connecting rod, as compared with the length of the crank, the less will be the pressure upon the guide.

Q. 99. (1899-1900.) If the diameter of a piston is 18 inches, the pressure at the beginning of the stroke is 130 lbs. (gage) per square inch, what is the pressure on the crank-shaft at this point? When the crank has turned to an angle of 60°, with the axis of the cylinder, the steam pressure has dropped to 115 lbs. gage per square inch, what is



the pressure on the crank-pin? What is the force tangent to the circle, described by the crank-pin?

Ans. 99. The area of 18 inch piston equals $18^2 \times .7854 = 254.47$ square inches.

Horizontal thrust at beginning of stroke equals $254.47 \times 130 = 33081.10$ pounds.

The horizontal pressure on crank-pin when at an angle of 60° to the axis of cylinder with a pressure of 115 lbs. per sq. inch equals $254.47 \times 115 = 29264.05$ pounds.

When the crank is in a position, termed dead center, that is, when piston connecting rods and crank are all in the same line, the horizontal thrust, simply produces a pressure on the bearings of the crank-shaft.

When the crank has turned to an angle of 90° or at right angle with the axis of the cylinder the pressure of the steam on the piston is all exerted in turning the shaft, and none on the bearings; this is because the pressure exerted is at right angles to the crank, or tangent to the crank circle.

By referring to the diagrams, when the crank is at 60° with the axis of the cylinder, the pressure is exerted in the direction of a c and a e.

The diagram line a d b represents the horizontal thrust of 29264.05 pounds.

The tangential thrust in the direction a c will be as a b : a f : : 29264.05 : X.

Substituting.

$$2'' : 1.73212 :: 29264.05 : X.$$

$X = 25343.545$ pounds, equals the force tangential to crank-pin circle a c.

SEE QUESTION 99.

Note.—The sine of the angle of $60° = .86606$. Multiplying the length of the line a b (2″) by the sine of the 60° (.86606) equals the length of the line a f equals 1.73212 inches.

The force, or thrust, in direction of a e is in proportion, as—

$$a\,b : a\,d :: 29264.05 : X$$

Substituting—

$$2'' : 1 :: 29264.05 : X$$

$X = 14632.025$ pounds, the pressure on the crank shaft when the crank is at an angle of 60° with the axis of the cylinder, or in the direction of the line a e.

Note.—The cosine of the angle of 60° equals .5. Multiplying the length of the line a b (2″) by the cosine of the angle of 60° (.5) equals the length of the line a d equals 1 inch.

The horizontal thrust is represented by line a b.

The thrust on crank shaft at 60° by line a e.

The thrust tangential at 60° by line a c.

Q. 106. (1899-1900.) How does the Corliss type of engines differ from the slide-valve type of engines?

Name the most important advantage in which the Corliss type excels.

After release, by the mechanical mechanism, how are the valves closed?

Ans. 106. The Corliss type of engine differs from the common slide valve type in that it has four valves, one at each end of the cylinder for the admission of steam and one at each end of the cylinder for the exhaust or escape of the steam.

The steam entering the cylinder at, or near, the boiler pressure for a certain part of the stroke, at which point the mechanism that opens the admission valves is released and allows the valves to close, cutting off the steam and allowing the remainder of the work to be performed by the expansion of the steam.

The Corliss type excels the slide valve type in that the steam is used expansively, consequently, more economically, also more convenient in the adjustment of the valve gear, as each valve is inde-

pendent of the others, less friction of the valve gear per unit of power developed, and a close regulation of speed.

After the valve mechanism is released, the steam valves are closed by dash-pots, or, as sometimes called, vacuum pots, consisting of a cast iron cylinder fitted with an air-tight piston attached to a bell-crank on the valve stem. As the opening mechanism opens the valve it raises the piston in the dash pot, forming a partial vacuum on the under side of the piston; at the point of cut-off the opening mechanism is released the atmospheric pressure on the upper side of this piston closes the valve rapidly. To prevent pounding a little air is admitted for cushioning the piston before striking the bottom.

Q. 107. (1899-1900.) An engine working at its maximum capacity, exhausting to the atmosphere, it is desired to increase the load 25 per cent, without an increase in steam pressure or the speed, how could this change be effected?

Ans. 107. When an engine exhausts to the atmosphere the steam which fills the cylinder at the end of the stroke has to be forced out against the atmospheric pressure, usually reckoned 15 lbs. per sq. in.

The nature of steam being such that a part of the atmospheric pressure can be removed.

One pound of steam at atmospheric pressure occupies about 1642 times as much space as it does in the form of water.

If this steam, when it is exhausted from the cylinder, is allowed to come in contact with cold water, or a cold surface within a vessel that is air-tight, it will be immediately condensed, occupying about 1/1600 of its original volume, creating a partial vacuum in the condenser, the water and air being removed by the air pump, allowing the piston to make its return stroke relieved from a portion of the atmospheric pressure of 15 lbs. per sq. in.

This reduction of back pressure is equal to a corresponding increase of the M. E. P., increasing the mean efficiency of the engine from 25 to 30 per cent. Therefore, the adding of a condenser will increase the capacity of the engine the required amount.

Q. 108. (1899-1900.) In good practice, how many expansions are advisable in a single-cylinder engine?

Why are more expansions objectionable? When more expansions are desired, how can they be obtained?

When the engine is so constructed as to properly give more expansion, what is this type of engine called?

Ans. 108. Usually in good practice it is desirable to have from 3 to 5 expansions in a single cylinder engine; an allowance of from 20 to 33 per cent cut-off, which is about the economical range of cut-off engines.

When more expansions are desired it is more practical to allow the expansions to take place in more than one cylinder. This type of engine is called a compound engine.

Q. 109. (1899-1900.) When the expansion takes place in more than one cylinder, for example, a two-stage compound, how are the number of expansions found, and are they effected by the cut-off in the low pressure cylinder?

Ans. 109. When the expansions take place in a two-stage compound the number of expansions are found by dividing the initial absolute pressure in the H. P. cylinder by the absolute terminal pressure in the L. P. cylinder, or it is the product of a number of expansions in the H. P. cylinder by the number of expansions in the L. P. cylinder.

Formula—

$$\frac{T}{t} \cdot \frac{t}{t^1} = \text{the number of expansions of the two cylinders.}$$

In which—

T = absolute initial pressure H. P. cyl.

t = absolute terminal pressure H. P. cyl.

t^1 = absolute terminal pressure L. P. cyl.

The number of expansions are not affected by the point of cut-off in the low pressure cylinder.

Q. 110. (1899-1900.) A compound engine, working with an initial pressure of 130 lbs. absolute pressure expanded to a terminal pressure of 26 lbs. absolute in the H. P. cylinder; then received and expanded to a terminal pressure of 8 lbs. absolute in the L. P. cylinder; find the total number of expansions in the two cylinders.

Ans. 110. 130 pounds absolute = initial pressure H. P. cyl.

26 pounds absolute = terminal pressure H. P. cyl.

8 pounds absolute = terminal pressure L. P. cyl.

The number of expansions taking place in high press. cyl. $= 130 \div 26 = 5$ expansions.

Low pressure cyl. $= 26 \div 8 = 3.25$ expansions.

Whole number of exp. $= 5 \times 3.25 = 16.25$ expansions.

By formula—

$$\frac{T}{t} \cdot \frac{t}{t^1} = \text{total number of expansions.}$$

$$\text{Substituting } \frac{130}{26} \times \frac{26}{8} = \frac{130}{8} = 16\tfrac{1}{4} \text{ total exp.}$$

Q. 111. (1899-1900.) For what purpose is a receiver placed between the two cylinders of a compound engine? What should be its relative capacity, and to which cylinder of the engine does the relation exist?

Does the disposition or arrangement of the cranks affect the size of the receiver?

What conditions would be favorable for the non-use of a receiver, the steam passing through the exhaust pipe from the high to low pressure cylinder?

Ans. 111. A receiver consists of an enclosed vessel or cylinder, generally provided with a steam jacket or some means for reheating the steam and to provide against loss of heat from radiation, etc. They are sometimes called re-heaters.

The H. P. cylinder exhausting into this receiver and the L. P. cylinder taking its supply from it.

It provides for a volume of steam close at hand to supply the low pressure cylinder without a serious reduction or drop in the pressure, and at a low maximum velocity.

The volume of the receiver is usually from 1 to 1.75 times the volume of the H. P. cylinder.

The larger ratio is more favorable to a straight back pressure line of the H. P. cylinder and steam line of the L. P. cylinder indicator cards.

The angle that the cranks are set to each other does affect the required volume of the receiver.

The most favorable condition for the non-use of a receiver is when the cylinders are placed in line with each other and both pistons are attached to the same crank, as a tandem compound, or, when the cranks are set at an angle of 180°, or nearly so, to each other.

Q. 112. (1899-1900.) Give the rule to find the receiver pressure necessary to balance the load on an engine?

What receiver pressure is required to balance the load on a 28″ × 52″ × 72″ cross-compound engine, the steam pressure 140 lbs. absolute; vacuum maintained at 28 inches?

Ans. 112. In order that the work of a compound engine may be divided equally, or nearly so, the receiver pressure should be proportional to the initial pressure of the H. P. cylinder, according to the ratio of the area of the piston of the H. P. cylinder and the area of the piston of the L. P. cylinder.

Rule.—To find the proper pressure to maintain in the receiver of a compound to balance the load.

Form the proportion:

As the area of the H. P. piston is to the area of the L. P. piston so is the required receiver pressure to the initial pressure less the receiver pressure (which acts as a back pressure).

As the areas of circles vary directly as the square of their diameters, it is not necessary to find the areas of the pistons use the square of the diameters instead.

Example—

Compound 28″ × 52″ × 72″.

Initial press. 140 lbs. ab.

X = the receiver pressure.

Then—

$28^2 : 52^2 : : x : (140 - x)$

$= 784 : 2704 : : x : (140 - x)$

The product of the extremes = 784 (140 — x)

The product of the means = 2704 x or 2704 x = 784 (140 — x) 784 (140 — x) = 109760 — 784 x.

Then 2704 x = 109760 — 784 x = 3488 x = 109760.

$$X = \frac{109760}{3488} = 31.47 \text{ lbs. ab. receiver pressure.}$$

28″ vacuum = 28 × .491 = 13.7 pounds.

31.47 — 13.7 = 17.77 pounds receiver pressure, as shown by the gage.

Q. 113. (1899-1900.) In good practice, how should the work be distributed on a cross-compound engine? How is this distribution brought about?

Ans. 113. The work should be so distributed that each cylinder will perform an equal share of the same; that the initial strains in each cylinder should be as near the same as possible. That the drop in pressure between the high pressure cylinder and the receiver should be as small as possible.

This distribution is brought about by the adjustment of the cut-off in the L. P. cylinder, shortening up the cut-off increases the receiver pressure, allowing the low pressure cylinder to perform a greater proportion of the work.

Lengthening out the cut-off has a vice versa effect.

Q. 114. (1899-1900.) What are the advantages derived from the use of compound engines over the use of simple engines?

What conditions in practice are necessary for the best economy in the use of multiple cylinder engines, condensing or non-condensing?

Ans. 114. The advantages of dividing the expansion among two or more cylinders, or the use of multi-cylinder engines are the use of higher initial pressures, a wider range of expansion, with a minimum

of cylinder condensation, avoiding excessive strains on the metal by sudden expansion and contraction.

Sizes of cylinders adapted to the work to be performed: A constant steam pressure and a constant load are required for economy.

Q. 115. (1899-1900.) Upon what depends the ratio for capacity of the several cylinders of multiple cylinder engines? Explain how the ratio is found.

Ans. 115. The ratio of capacity of the cylinders depends upon the range of temperature or pressure desired, or the ratio of the initial pressure to that of the desired terminal pressure in the following cylinder; this is the relation that the volume of the H. P. cylinder bears to the L. P. cylinder.

Rule.—Divide the absolute initial pressure of the first cylinder by the absolute terminal pressure of the last cylinder and multiply this quotient by the desired per cent of cut-off in first cylinder.

Q. 116. (1899-1900.) What should be the ratio of capacity of the cylinders of an engine using steam at an initial pressure of 135 lbs. absolute per square inch, expanding to a terminal pressure of 10 lbs. absolute in the L. P. cylinder, the point of cut-off 30 per cent of the length of the stroke?

Ans. 116. 135 lbs. absolute = initial pressure.
10 lbs. absolute = terminal desired in L. P. cyl.
30% = cut-off.
Then—
$135 \div 10 = 13.5$ expansions.
$13.5 \times 30 = 4.05$ ratio of capacity.
Or, 1 : 4.05 = ratio of capacity of the H. P. cyl. : L. P. cyl.

Q. 117. (1899-1900.) Give rule, or formula, for finding the approximate H. P. of a compound engine.

Ans. 117. Rule for finding the approximate H. P. of a compound engine—

Assume that the entire work is to be done and the expansion all taking place in the L. P. cylinder.

Then, 1 + hyp. log. of the total number of the expansions, multiplied by the terminal pressure in the L. P. cylinder will equal the average mean effective pressure, due to the expansions; this product multiplied by the area of the L. P. cylinder's piston and by the piston speed in feet per minute; this product divided by 33,000 will give the approximate H. P. of the engine.

Formula—
H. P. = horse-power of compound engine.
H = 1 + hyp. log. of total number of expansions.
T = terminal pressure, L. P. cylinder.
E = average M. E. P. due to number of expansions.
S = piston speed in ft. per minute.
A = area of piston.
E = T. H.
Then—

$$\text{H. P.} = \frac{\text{A.S.E.}}{33{,}000}.$$

Q. 118. (1899-1900.) Required size of cylinders for a compound engine, condensing of 2,000 H. P., 5 feet stroke and 72 R. P. M., or 720 piston feet per minute.

Boiler pressure 140 lbs. absolute, an allowance of 5 lbs. for drop between the boiler and throttle.

Terminal pressure L. P. cylinder 6 lbs. per square inch. Back pressure 3 lbs. per square inch.

Prove the work by rule found in Question 117.

Ans. 118. The theoretical diameter for a two-stage compound of 2,000 H. P., 60-inch stroke, 72 R. P. M.

Boiler pressure 140 lbs. absolute.

Terminal pressure 6 lbs.

Back pressure 3 lbs.

Drop in pressure between boiler and throttle 5 lbs.

$140 - 5 = 135$ lbs. initial pressure absolute at throttle.

$135 \div 6 = 22.5$ total number of expansions.

The expansion in each cylinder is equal to $\sqrt{22.5} = 4.74$.

The terminal pressure in the H. P. cyl, is equal to $135 \div 4.74 = 28.48$ lbs. absolute.

Average—

M. E. P. of H. P. cylinder is equal to (1 + hyp. log. of 4.74) 28.48 = 72.79 lbs. absolute.

$72.79 - 28.48 = 44.31$ lbs. = M. E. P. of H. P. cyl.

Average—

M. E. P. of L. P. cylinder is equal to (1 + hyp. log. of 4.74) 6 = 15.34 lbs. absolute.

$15.34 - 3 = 12.34$ pounds. M. E. P. of L. P. cylinder.

It is desirable to have the cylinders so proportioned that the work, with the above conditions, one-half of which, to wit, 1,000 H. P., be performed in each cylinder.

Then, the area of the low pressure cylinder will equal

$$\frac{33{,}000 \times \text{H. P.}}{\text{piston speed in ft.} \times \text{average M. E. P.}}$$

Substituting—

$$\frac{33{,}000 \times 1{,}000}{720 \times 12.34} = \frac{33{,}000{,}000}{8{,}884.8} = 3{,}714.21 \text{ sq. in.}$$

the area of L. P. cyl.

$$\frac{\sqrt{3{,}714.21}}{.7854} = 68.76 \text{ in., diam. of L. P. cyl.}$$

Area of the high pressure cyl. will equal—

$$\frac{33{,}000 \times 1{,}000}{720 \times 44.31} = \frac{33{,}000{,}000}{31{,}903.2} = 1{,}034{,}379 \text{ sq. in.}$$

$$\frac{\sqrt{1{,}034.379}}{.7854} = 36.29 \text{ in., dia. of H. P. cyl.}$$

The size of the compound engine as per the conditions stated in question will be—36″ × 69″ × 60″—at 72 R. P. M. with 140 lbs. absolute boiler pressure, 22.5 expansions, or 4.74 expansions in each cylinder exhausting into condenser against 3 lbs. back pressure, or into a vacuum of $14.7 - 3 = 11.7$ lbs.

11.7 lbs. × 2.036 = 23.82 in. vacuum.

$$\text{The ratio of cylinder} = \frac{69^2}{36^2} = 3.67.$$

The engine under the above conditions will develop 2,000 H. P.
Proof by rule found in Ans. 117.

Whole number of expansions $= 135 \div 6 = 22.5$, $(1 + \text{hyp. log. of } 22.5) = 4.11353$.

$6 \times 4.11353 = 24.68118$ lbs. effective pressure.

Area L. P. piston = 3,729.38 sq. in.

Speed of piston = 720 ft. per min.

Average effective pressure = 24.68 lbs.

Then—

$$\frac{3{,}729.38 \times 720 \times 24.68}{33{,}000} = 2{,}012.05 \text{ H. P.},$$

a difference only of 12.05 horse-power.

Q. 119. (1899-1900.) Describe the manner of attaching the indicator to an engine. What care should be taken in such preparation for the attachment? How to obtain the drum-motion and what care should be taken?

Describe the manner of taking diagram, and note the important data usually taken.

Ans. 119. The indicator is attached to the end of the cylinder, through holes drilled and tapped for ½″ pipe, into the side or top, whichever is the most convenient, to connect with a reducing motion, attached to the crosshead.

The holes must be drilled in such a position that they will communicate with the clearance space and not become covered by the piston when it is at the extreme end of the cylinder; the indicator should be attached as direct as possible to the cylinder.

In most engines the holes are drilled and tapped in the shop before it is sent out. Some are not, however, and in those that are not care should be taken to locate the holes and to keep the chips from the drill from getting into the cylinder, especially the front end.

As the length of the diagram represents the travel of the piston for ½ revolution, or one stroke of the engine, and the length of this diagram is determined by the rotation of the paper drum, this motion must be taken from some part of the engine which has a motion coinciding with that of the piston; the crosshead is the most convenient part for this purpose.

This drum motion, or reducing motion, as it is called, is obtained by the Brumbo pulley, or the pantograph, reducing wheels, and numerous other devices, so long as they reduce the motion proportionately to the stroke of the engine and parallel with the crosshead or piston; so that when the crosshead has made ¼ of its stroke the pencil will have traveled ¼ the length of the diagram, and so on.

In taking diagrams from engines, the indicators should be thoroughly warmed up by opening the steam cock between the indicator and the cylinder, the working parts should work very smooth, the spring selected to give the diagram should be one that will make a diagram from 1½ to 2 inches high; dividing steam pressure per gage by about 1¾ gives a scale of spring that makes a very good height for diagram.

The pencil should be sharp, smooth, and so adjusted that when the pressure is applied it will make a smooth, fine, distinct line. The cord leading from the crosshead or reducing motion to the indicator should be so adjusted that the paper drum in rotating will not bring up against the stops.

After placing the paper around the drum taut and smooth, start the paper drum in motion, open the shutoff cock, allowing steam on the under side of the piston. Press the pencil against the paper for one revolution or more, then shut off the steam to the indicator and

again press the pencil to the paper and draw the atmospheric line, which is drawn with the atmospheric pressure on both sides of the piston.

As much of the following data as can should be obtained and noted on the diagram: The date, the hour of taking the diagram, the type or make of the engine, which end of cylinder and which engine if one of a pair, the diameter of cylinder, and length of stroke, the diameter of the piston rod, the number of R. P. M., the steam pressure, by gage, at the boilers and at the engine, atmospheric pressure by barometer, the vacuum, by gage, in the condensers (if the engine is a condensing type), temperature of feed water at boilers, the receiver pressure by gage if the engine is a compound, if not note the back pressure per gage, and the scale of spring used in taking the diagram; also note any other matter connected with the plant that may come to your notice.

Q. 120. (1899-1900.) What is the value of the indicator diagrams for the successful operation of a steam plant?

Describe the workings and use of a planimeter.

Ans. 120. The indicator diagrams are the result of two motions—thus: The horizontal of the paper in exact correspondence with that of the piston, it represents the stroke of the engine on a reduced scale, and the vertical movement of the pencil in exact ratio to the steam pressure, exerted in the cylinder; consequently, it represents by its length the stroke of the engine, by its height at any point, the pressure on the piston, at a corresponding point in the stroke.

The shape of the diagram depends very much upon the manner in which the steam is admitted to and released from the cylinder of the engine. It shows the arrangement of the valves for admission of steam, cutoff, release and compression of the steam.

The adequacy of the ports and passages for admission and exhaust, and when applied to the steam chest, show the adequacy of the steam pipe.

The amount of power developed, the quantity lost in various ways —by wire drawing, back pressure, premature release, or any other maladjustment of the valves.

It has proved itself very useful to the designers of steam engines in figuring out the distribution of the horizontal pressure on the crank pin, the angular distribution of the tangential components of the horizontal pressure; in other words, the rotative effect around the path of the crank.

Taken in combination with a measurement of feed water and coal used, the economy of the plant can be found.

The degree of excellence to which the steam engine of to-day has been brought is due principally to the use of the indicator, as a careful study of the diagrams and different conditions, load, pressure, etc., is the only means of becoming familiar with the action of steam in the cylinder of an engine. The indicator furnishes many other items of importance when the economy of the generation and the use of steam is to be considered.

The planimeter is an instrument designed to measure the areas of irregular figures. It is operated by moving a tracer, with which it is fitted, over the lines of the diagram or figure to be measured, and records the area upon a graduated wheel and Vernier scale. Some of the instruments are made to read the M. E. P. or the I. H. P. direct from the wheel without the use of any figures. In measuring the I. H. P. of cards much time and labor can be saved by the use of the planimeter.

Q. 1. (1900-1901.) Give three ways of establishing the theoretical expansion curve on an indicator diagram, accompanying answer with a sketch of each method.

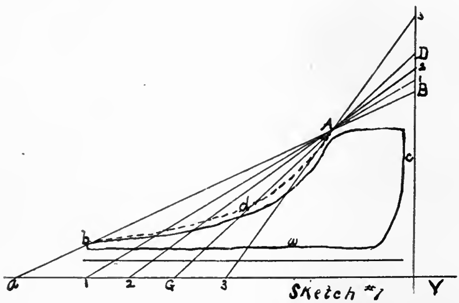
Ans. 1. To establish the theoretical curve it is well to remember that the pressure of steam varies inversely as its volume; from this consideration we can readily locate any number of points in the curve.

Again, all pressures must be measured from perfect vacuum, and clearances must also be taken into account.

By referring to the sketches we find the vacuum line denoted by V, and the clearance line by C; the vacuum linė laid off by the scale of the spring, 14.7 pounds below the atmospheric line, and the clearance line C the distance h from the beginning of the diagram, representing the added length of the cylinder that would represent or equal the capacity of the clearance space on one end of the cylinder.

There are several ways of establishing the points in the theoretical curve. The curve may be drawn from any point in the real curve, the only restriction being that the point must be selected when the steam valve and the exhaust valve are closed.

The following are several methods of establishing the theoretical curve:



Sketch #1

Through the point of release b, draw any line as aB, and make AB equal to ab. Then draw any other line as GD, and Gd, equal to AD, then will d be a point in the curve bA, as shown by the dotted lines above the real curve. By drawing a number of lines through the point A, and following the same method in regard to laying off the distances any number of points in the curve may be located.

The following geometrical method for locating the points in the theoretical curve is perhaps the most used:

Select any point as I in the actual curve and from this point draw a vertical line to J, on the line B; the line B representing the boiler pressure, or, it may be a line drawn at any convenient height.

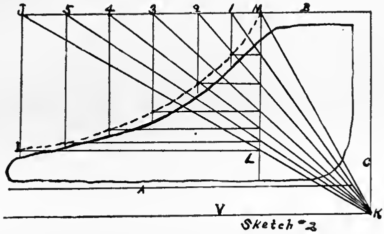
From the point J draw a line to the point K, K being the intersection of the vacuum and clearance line; from I draw the line IL, parallel with the atmospheric line and at right angles to IJ.

From L the point of intersection on the diagonal line JK and the horizontal line IL draw the vertical line LM.

The point M is the point of theoretical cut-off. Fix upon any number of points as 1, 2, 3, 4, 5 on the line B and draw from these points lines to the point K; from the intersections of these lines with the line LM draw horizontal lines, and from points 1, 2, 3, etc., draw

vertical lines parallel to IJ. The intersection of these horizontal and vertical lines will establish the desired points in the theoretical curve.

On the diagram draw vertical lines, commencing at the clearance line spacing equal distances apart and number them as shown in



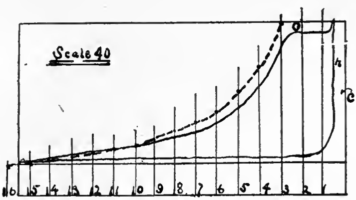
Sketch #3

sketch. It is not necessary to pay any attention to coming out even with the end of the diagram, and the more numerous these vertical lines are the greater the accuracy in developing the curve.

Selecting the point 14 on the line V, the pressure represented by the scale of the spring, we find to be 18 pounds absolute.

The number of volumes is according to the units adopted and represented by the distance apart of the vertical line 14, hence to find the pressure for any other line:

Multiply the pressure by the number of lines and divide by the



Sketch #3

number of lines upon which it is desired to determine the pressure. For example, $18 \times 14 = 252$. If we divide this by 7, for instance, it equals 36 pounds to be set off by the scale of the diagram on line 7.

By following out the above method and connecting the points together the theoretical curve for the diagram will be established.

Q. 2. (1900-1901.) Of what advantage is the theoretical curve and what does it indicate or represent? Also describe the adiabatic and isothermal curves. Which one is used in plotting the theoretical curve? Why?

Ans. 2. The defects in engines as revealed by the indicator diagram are most clearly understood by comparing the diagram of the engine in question with a theoretically perfect diagram—that is, one which would be obtained from an engine in which both the designs and the adjustments were perfect in every way.

Adiabatic curve is defined as the curve of no transmission of heat.

Isothermal curve is defined as the curve of equal temperature and is a common or rectangular hyperbola.

The isothermal curve is usually used in plotting the theoretical curve.

The reason why this curve is usually used is that according to "Mariotte's" law the volume of a perfect gas, the temperature being kept constant, varies inversely as its pressure, and in calculations of the mean pressure of expanded steam in engines it is generally assumed that steam expands according to "Mariotte's" law, the curve of the expansion line being a hyperbola.

Q. 3. (1900-1901.) Explain fully how you ascertain by card the number of pounds of water consumed per indicated horse power (I. H. P.) of an engine, either single high pressure or compound condensing.

Ans. 3. The indicator diagram enables us to find approximately the amount of steam consumed by the engine.

The rule for calculating the number of pounds of steam consumed by an engine per horse-power is as follows:

Rule—

Take two points, one on the expansion line before release and one on compression line equally distant from the vacuum line. Find by the scale of the spring used the pressure of steam at these points, and from the steam table find the weight of a cubic foot of steam at that pressure. Multiply this weight by the distance between the two points and by the constant 13750.

Divide the product by the M. E. P. and by the length of the diagram.

The result will be the number of pounds of steam consumed per I. H. P. per hour, as shown by the diagram.

This computed consumption of steam is for various reasons always less than the actual consumption.

The difference between the theoretical water-consumption found by the rule and the actual consumption as found by test represents "water not accounted for by the indicator" due to cylinder condensation, leakage through ports, radiation, etc.

In relation to multi-cylinder engines the supposition is that the work is done in one cylinder.

Q. 4. (1900-1901.) Explain the various methods of obtaining the mean effective pressure (M. E. P.) from indicator cards.

Ans. 4. In general practice, the M. E. P. is found by the use of a planimeter or by computing by the use of ordinates. It can also be found by plotting on cross-section paper.

The planimeter, as has been heretofore stated, is an instrument by which the area of irregular surfaces may be accurately measured. Some instruments are so constructed as to read the M. E. P. direct, while others give the area only. Having the area given, the M. E. P. is found by multiplying the area in square inches by the scale of the spring and dividing this product by the length of the diagram.

The computing by the means of ordinates is quite generally understood without much explanation; the total number of ordinates—that is, their length—divided by the total number equals their mean length in inches. This multiplied by the scale of the spring equals the M. E. P.

Q. 32. (1900-01.) How would you determine if the steam pipe leading to your engine was large enough, that is, of sufficient diameter?

Ans. 32. The sufficient diameter of steam pipe for the work of the engine could be determined by the use of the indicator both on the engine cylinders and on the pipe proper.

If in indicating an engine, the drop of initial pressure, the falling off of the steam line, would prove conclusively that there was too contracted area in the steam passages of the engine or that the pipe was too small, or both, to locate the trouble the indicator can be placed on the steam chest; also on the pipe and a diagram taken while the engine is working at its usual or rated load. The sudden falling off of the pressure would indicate the trouble.

Q. 34. (1900-01.) Give in a general way your practice for using and handling of valves. Also the best practice as to kinds of valves to use and not to use.

Ans. 34. A general rule for locating and handling valves is to avoid forming water pockets. Junction valves should never be placed close to the boiler if the main steam pipe is above the boiler, but put it on at the highest point of the junction pipe.

Never let a junction pipe run into the main at the bottom, but into the top or side.

Always use an angle valve when convenient, as there is more room in it.

All gate valves of size 4 inches and upwards should be by-passed; this saves the gate and seat of valve from wear and is also convenient in equalizing the pressure before opening the large valve. In cutting in a boiler a by-pass will be found very convenient in equalizing the pressure before opening the main junction valve. Blow-off valves should be opened wide open to allow sediment to pass out and not lodge in the valve, thus ruining it when closed. Globe valves should not be used on indicator pipes.

For water always use gate valves, or angle valves, or stop-cocks.

Valves with renewable discs are recommended in some cases. It is also recommended that in case of inspection of a boiler connected to others working, as a precaution, that the junction pipe be disconnected and a blank flange, or a blank be inserted between the flanges, making the boiler surely safe for inspection or cleaning.

Q. 36. (1900-01.) For what purpose is a separator placed on a steam pipe; and for the greatest efficiency where should it be placed?

Ans. 36. The function of a separator is to remove from vapors and gases the liquids and solids which they carry along with them.

Thus a live steam separator is intended mainly to remove the entrained water from steam, while the separator placed in the exhaust piping when the exhaust steam is to be condensed and again used in the boilers is intended to remove the grease which it has accumulated in its passage through the engine.

The use of dry steam in an engine cylinder is very important, not only because an accumulation of water is a menace to safety, but also because entrained water involves a very considerable reduction in the economy of operation.

The water carried into the steam cylinder not only carries away heat from the boiler which is incapable of doing any work in the engine, but it also materially increases the initial condensation, one of the most important losses of power in the engine.

Hence there should be some device provided to ensure dry steam.

The principles upon which the action of steam separators should be based are as follows:

In the first place, they should be constructed in such a way that the momentum which has been acquired by the liquids and solids has been destroyed. This has been accomplished by baffle or deflecting plates, which alter or reverse the flow of the steam, or by allowing it to expand and give the heavier particles time to fall by the action of gravity. After this has been accomplished it is important to prevent the separated water from being again picked up and carried along by the purified gases.

Finally, care must be taken that an ample and easy passage is afforded to the current of steam, so that there will be no loss of energy from friction.

A separator should be placed as close to the engine cylinder as possible.

There are several well known types of proved merit, made for both horizontal and vertical pipes, allowing in some cases to placing directly over the cylinder.

Q. 37. (1900-01.) If a number of engines are receiving their steam supply from a common steam main, where would you locate the separator?

Ans. 37. Should there be a number of engines connected to the steam main and only one separator used, it would be placed at the last engine. This answer might be modified in certain conditions in which the pipe was not in the same plane. The proper way if the engines were of fair size, to place a separator at each engine. The piping off to the engines would determine the position of the separator in the line of the main steam main.

There might be instances where the separator would be placed near the first engine. If we take into account the difference in the specific gravity of water and steam, the momentum obtained by the entrained water as it is swept along with the steam we will see that the heavier particle will have a tendency to keep in a right line direction rather than take to a turn in direction, thus if the first engine was piped off from a side outlet or taken from the top of the pipe there would be a tendency for the water to follow the straight pipe. Should the steam main take a turn at right angles at the first engine then the probability is that the separator should be placed near first engine.

Q. 38. (1900-01.) In erecting a steam main of considerable length, what do you consider the best practice for the return of the condensation?

Ans. 38. In erecting a steam main of considerable length a large drum or separator should be provided near the engine, for trapping the water condensed in the pipe.

A steam drum 3 feet in diameter and 15 feet high has given good results in separating the water of condensation of a steam pipe 10 inches in diameter and 800 feet long.

There are several different ways of conducting the water of condensation back to the boiler. The steam loop, the Holly system, pump and receiver system, the return trap system, etc.

Where there are a number of returns of the same pressure coming back bring them to a receiver and return them automatically with pump. This system gives about as little trouble in handling as any. Still the other methods have their advocates.

Q. 39. (1900-01.) Is it safe practice to return the condensation from the steam cylinders of pumps or engine's cylinders to the boiler? Explain your reasons, "pro and con," setting forth dangers, etc.. and preventives for eliminating said danger.

Ans. 39. In localities where a high tariff exists on water, it is deemed advisable to save and re-use all of the drips of condensation. In this case, care should be taken to eliminate from the exhaust steam as it passes from the steam cylinders all oils or greases. It is also advisable to use in such cases a high grade of mineral oil for cylinder lubrication.

In discussing the reasons "pro and con," they could be made the subject of an extended paper, but while it is easily recognized that it is better not to return them to the boiler, economy says in this instance that we must.

A discussion can easily arise as to the merits and demerits of open vs. closed heaters, etc.

In which ever way it is done constant care should be taken that all apparatus is kept in proper condition and the water returned as free from oil and foreign elements as possible.

It is good practice to feed in some service water at all times to make up what little deficiency is lost by evaporation or leaks.

Q. 40. (1900-01.) In connecting drips from a number of engines into a common drip line, what safeguard should be applied?

Ans. 40. Several drip lines (all under the same pressure) connected to a main drip line, should have a check valve to prevent the steam or condensation from backing up from any individual line.

Q. 41. (1900-01.) What are the advantages of high piston speed?
What kind of service requires high rotative speed? Why?
Why should high speed engines run under high pressure?

Ans. 41. The advantages of high piston-speed over slow-speed engines may be briefly stated as follows:

First—For a given steam pressure and cut-off the power of an engine varies directly as its speed. There are four factors which determine the power of an engine, viz:

(a) The mean effective pressure on the piston.
(b) The length of the stroke.
(c) The area of the piston.
(d) The speed.

In other words, an engine of a given diameter and length of stroke, acting under a given mean effective pressure, will develop power in proportion to its speed, and if the speed is doubled its power will also be doubled, and so to obtain a given power under a given mean effective pressure we need make an engine only half as large if we double its speed.

This constitutes the first argument for high speeds, economy both in first cost and in space.

Secondly—Where power is transmitted to shafting or directly to machine running at a much higher speed, it can be performed more efficiently if the ratio of the speeds is not too great.

In many cases when the power is transmitted by belting the ratio of speed is too great to admit of transmission in a single step, since the arc of contact on the driven pulley would be too small to prevent slippage of the belt. In such cases it is common to use an intermediate shaft which performs no other duty than to make the reduction more gradual, and thus insure a satisfactory running of the belt.

By increasing the speed of the engine this is done away with in many cases.

In the case of dynamo machines it is now common practice to couple the shaft of the engines and dynamo direct without any belting whatever.

In spite of all that may be said against this practice, it cannot be denied that it saves a very considerable amount of valuable space.

Thirdly—It is claimed for high-speed steam engines that the economy in the use of steam far exceeds that of the older forms of slow-speed engines.

There is no doubt a great deal of justice in this claim, because one of the main losses in the engine, viz., the cooling of the cylinder walls and passages during exhaust and re-evaporation, is greatly reduced. The disadvantage of admitting steam by the same passage through which it exhausts is clearly demonstrated in the increased economy of the Corliss type of engine, where this is not the case. As far as re-evaporation is concerned, it is obvious that the cylinder walls are chilled very considerably during this process, and the more steam passed through the engine in a given space of time the less will be the re-evaporation. Hence the increased economy of the high-speed engine.

It is a fact that the uniformity and smoothness of running of the high-speed engines make them particularly adapted for dynamo running. This uniformity of running is in part due to the fact that the influence of the fly-wheel is greatly enhanced and partly to the steadying influence of the reciprocating parts. It is a well-known fact that the steadying influence of a fly-wheel is proportional to the square of its speed.

For instance, if one engine runs twice as fast as another of same design and the same weight of fly-wheel, it will run four times as steady. Now, in every steam engine the pressure is a maximum at the beginning of the stroke, decreasing as the stroke advances until the end, when it is a minimum; hence it is evident that the action of the reciprocating parts, which is to absorb or store a portion of the pressure during the first half of the stroke and restore it during the second half, has the effect of tending to keep the pressure on the crank uniform during the entire stroke, or, in other words, to steady the running of the engine.

High-speed engines must be high pressure engines—that is, the initial steam pressure must be sufficient always to set the reciprocating parts in motion, and the pressure should never be reduced by the means of the throttle-valve, otherwise the engine will be subjected to strains which will impair its life.

The steam passages and parts should be of ample size, the higher the speed the larger the passages, otherwise the pressure will be reduced before entering the cylinder.

The steam should be cut off early, and a moderate amount of compression to provide cushioning the reciprocating parts as they come to rest at the end of each stroke should be provided for by an early closing of the exhaust valve.

Q. 42. (1900-01.) What are rotary engines?
Why are they not more extensively used?
What are the principal sources of loss in steam engines?
What is the principal source of waste in the engine proper?
How may it be reduced?

Ans. 42. In the rotary engine there is no reciprocating motion whatever, the force of the steam being used to produce at once a motion of rotation. Rotary steam engines other than steam turbines have been invented by the thousands, but no one has attained a commercial suc-

cess. The possible advantages, such as speed and the saving of space, to be gained by the rotary engine are overbalanced by its waste of steam.

In designing and constructing steam engines for additional economy in the use of fuel, and yet with all that has been done in this direction since the time of James Watt, the steam engine is still a very wasteful machine, and only a small percentage of the energy contained in the fuel is actually converted by the steam engine into useful work.

There are certain losses of energy which it has hitherto been impossible to avoid, and so long as these must be incurred so long will the process of transforming the latent energy of the coal into mechanical work by the means of the steam engine be a wasteful one. It has been demonstrated that in the use of high-speed non-condensing type that of the total energy contained in the fuel that only from 5 per cent to 10 per cent is available at the shaft of the engine. A large part of this loss of energy occurs in the steam generator, due in part to the high temperature of the gases escaping into the chimney, which is necessary for the production of the draught, and partly to the excess of air over and above that necessary for the complete combustion of the fuel. Additionally there are losses due to radiation, to leakage and to the heat carried away in the ashes.

The principal source of waste in the engine proper is cylinder condensation and re-evaporation. The condensation of steam in the cylinder is greater, the greater the surface exposed for a given weight of steam passing through the engine, consequently it is not as great proportionately in large engines as in the smaller ones.

Obviously, also, it is proportional to the range of temperature to which the cylinder is exposed, and it is for this reason that multiple expansion engines are more economical.

As for the condensation in the steam passages, it has been found that this could be almost entirely eliminated by closing the exhaust before the end of the stroke, so as to compress the steam and thus raise the temperature of the walls and passages, or more effectually by providing separate passages for admission and exhaust.

Losses in the engine proper by the presence of moisture in the steam cylinder, which is carried into the cylinder with the steam from the boilers or is produced by the condensation on the cylinder walls or in the steam passages, is re-evaporated during the expansion and exhaust periods, and re-evaporating, abstracts heat from the steam. Very little of this heat which is used in this way is returned to the engine as useful work, and consequently the presence of moisture may be said to rob the engine of an amount of useful energy proportional to the heat required for its evaporation.

It is, therefore, a matter of economy to prevent the entrance of water to the cylinder or its formation by condensation on the walls of the cylinder and in the steam passages.

Q. 44. (1900-01.) Which is the most economical type of engine, and why?

What is the cause of cylinders wearing unevenly?

How can it be avoided?

What is meant by the term "clearance"?

Why is it a necessity and how can it be determined in a given engine?

Ans. 44. The four-valve and the Corliss type of engines are more economical than those in which the same passages are used for both admission and exhaust.

The losses of heat due to radiation may be effectually prevented by surrounding the cylinder with non-conducting material.

The steam jacket is also frequently used and is effective in reducing the losses due to initial condensation.

It is a general impression among engineers that the cylinders of very large horizontal engines are more liable to wear oblong than those of vertical engines of the same bore; but experience and observation have proved this to be a mistaken idea.

The trouble is frequently due to imperfect alignment, and it is difficult to imagine why an engine piston should exert any pressure against the cylinder walls, other than that due to gravity, when all the reciprocating parts are perfectly true with the center line of the engine and with each other.

Care should be taken in packing the rod that there should be no inequality in the packing, as any material inequality may throw the engine out of alignment.

The wear which would occur on the bottom of large cylinders of large horizontal engines on account of the weight of the piston is frequently avoided by extending the rod through a stuffing-box in the outer cylinder head.

The term clearance is understood to mean the unoccupied space between the piston and cylinder-heads when the crank is on the dead center; but it also applies to the space between the cylinder and the face of the valves.

The amount of clearance of any engine affects its economy; that is, if the clearance is small, the engine will be more economical than if large; for obvious reasons a certain amount of clearance is a necessity to prevent the piston from striking the heads of the cylinder, due to the wearing of boxes and pins or an unequal adjustment of the different reciprocating parts.

The most accurate method of ascertaining the exact amount of clearance is to weigh up a certain amount of water, place the engine on the dead center, and then from this weighed or measured water fill the clearance space up to the face of the steam valve; reweighing the water remaining and subtracting from the first weight will give the number of pounds that are required to fill the clearance space, which can be reduced to cubic inches, and in comparison with the cubic contents of the cylinder, the percentage is easily arrived at.

Q. 45. (1900-01.) What consideration determines the length of connecting rods?

How long are they usually made?

What is the function of the cross-head?

What are three different forms of cranks?

Where would they be used?

Explain the difference of the terms "throwing over" and "throwing under"?

Which way is advisable?

What are the disadvantages of center cranks?

Of what material should they be constructed?

Ans. 45. The length of stroke is one of the principal considerations that govern the length of the connecting rod. The connecting rod, like the piston rod, is subjected to both a tensile and compressive stress; undue stress, due to accidents, etc., must be taken into consideration. Long connecting rods have many advantages, but the longer they are the greater must be their thickness, and they are not as economical in the use of material as the short connecting rods. For long-stroke engines they are generally made from two to four times the length of the stroke. The usual length for high-speed engines is five times the length of the crank.

The cross-head is that part of the engine which, moving between guides, preserves the rectilinear motion of the piston rod and at the same time supplies a bearing, called a wrist-pin, for the rocking motion of one end of the connecting rod.

A crank is a simple lever, at one end of which acts the steam pressure which is transmitted to it by the reciprocating parts, while the other is secured to the shaft of the engine. It is the final link in the transformation of reciprocating into rotary motion. The three different forms of crank are the side crank, disc crank, and the center crank. The center cranks are used when the shaft extends on either side of the crank. They are usually forged in one piece with the shaft, but weaken it somewhat.

The side and disc cranks can be used in any case where the connecting rod is on the side of the engine. The advantage of the disc over the crank is that it affords better facilities for balancing.

An engine throws over when the crank-pin traverses the upper portion of its travel while the piston is moving towards the main shaft and throws under when the crank-pin traverses the lower portion of its travel while the piston is moving toward the main shaft.

In the first case the stress on the guides is downward, which is preferable; in the second case the stress is upward. Engines are usually built to throw over, and it is only advisable to throw under in such cases where the transmission is such that the tight side of the belt is on the top of the pulley, which is never advisable.

Q. 46. (1900-01.) What is an eccentric?
In what respect does it differ from a crank?
When is it used in preference to a crank? Why?
Explain the throw of the eccentric.

Ans. 46. An eccentric is substantially a crank, with its pin enlarged in diameter so as to enclose the shaft on which it is placed within its periphery. It gives exactly the same motion that would be obtained from an ordinary crank of equal throw.

Eccentrics are generally used for converting rotary into reciprocating motions, while cranks are used for the opposite purpose, although the latter can accomplish both results.

The principal reason why eccentrics are used instead of cranks to actuate the valve gear is because the motion must generally be taken off at some point near the middle of the shaft, hence a center-crank would be required, which would weaken the shaft. The distance between the center of the eccentric sheave and the center of the shaft is called the throw of the eccentric or eccentricity.

Q. 47. (1900-01.) Calculate the diameter of a shaft that will safely transmit 1,000 HP. at 100 R. P. M., considering torsional stresses only.

If the transverse stresses were taken into consideration, how would you proceed to find the true diameter?

Ans. 47.

Rule—

(a) If steel, multiply the H. P. to be transmitted by 75 and divide the product by the number of revolutions per minute. Extract the cube root of the results, which will be the required diameter of the shaft in inches.

(b) If wrought iron, multiply the H. P. to be transmitted by 100, then proceed as above.

Example—Use formula for steel shaft.

$$\sqrt[3]{\frac{1000 \times 75}{100}} = \sqrt[3]{750} = 9.0856 \text{ inches} = \text{dia. of shaft.}$$

The usual method to determine the proper diameter for the crank shaft is to calculate it according to the above rule, then consider it as a beam carrying a load equal to the total maximum pressure of the steam on the piston, and determine what diameter would be necessary to safely carry the load. The greater of the two results will be the proper diameter for the shaft.

Q. 48. (1900-01.) What are the functions of a "fly-wheel"?

Where should the bulk of the metal be concentrated?

Should it be evenly balanced?

How would you proceed to find the safe weight of a fly-wheel for any size or style of engine?

Suppose an engine is 12″ × 24″, making 140 R.P.M., diameter of wheel 6 feet; what would be the proper weight of the wheel?

Ans. 48. The function of a fly-wheel is to equalize the motion whenever either the power communicated or the resistance to be overcome is variable. In one case where the fly-wheel is used to overcome a variable resistance, it may be considered a conservator of power.

In the other case the fly-wheel may be said to be a distributer of power.

The fly-wheel, as before stated, is a regulator and a reservoir, and not a creator of motion. As regularity of motion is of much greater importance in some cases than in others, the weight and diameter of the fly-wheel must depend upon the work and character of the machinery it is intended to drive; so that in proportioning a fly-wheel to a given engine, attention must be paid to many particular circumstances rather than to any given rule.

The effectiveness of the fly-wheel in steadying the motion of the engine depends upon the distance of the metal from the center. For this reason the material of which the fly-wheel is composed should be concentrated as much as possible in the rim. The steadying action also varies as the square of the speed of the rim. Hence within certain limits increasing the diameter saves weight.

The speed of the rim is rarely above 80 feet per second, and if carried beyond 200 feet per second the strains produced by centrifugal force would probably be sufficient to rupture the wheel.

Great care should be taken in erecting fly-wheels to see that they are perfectly balanced—that is, that the center of gravity of the wheel coincides with the center of the shaft.

Rule—For finding the weight of a fly-wheel having the size of the cylinder, the diameter of the wheel and the revolutions per minute given—

First—Multiply area of the piston by the length of stroke in feet. Multiply this product by constant, 12,000,000.

Second—Square the number of revolutions. Multiply this by the square of the diameter of the wheel in feet.

Divide the first result by the second and the quotient is the proper weight of the fly-wheel in pounds.

Example—As per question—

12 in. dia. = 113 in. area.

First $113 \times 2 \times 12{,}000{,}000 = 2{,}712{,}000{,}000$.

Second $140^2 \times 6^2 = 705{,}600$.

$2{,}712{,}000{,}000 \div 705{,}600 = 3{,}857$ lbs.—The weight of the fly-wheel.

Q. 49. (1900-01.) Explain the terms: "Valve gear," "releasing valve gear," "automatic cut-off," "positive cut-off," "riding cut-off" and "reversing gear."

Ans. 49. The term valve-gear embraces all intermediate connections between the eccentric on the driving-shaft and the valves, and is applicable to all mechanical arrangements employed for working the valves of steam engines.

Releasing valve-gear is an arrangement in which the valve is liberated from the control of its moving agent, and allowed to close in obedience to the action of a spring, weight or other force independent of that which opened it.

An automatic cut-off valve-gear is one in which the movement of the cut-off valve is so controlled by the governor as to cut off the steam as early or as late in the stroke as may be required, to maintain the desired uniformity of speed, under variations of load and pressure.

Positive cut-off is an arrangement of valve-gear by which the expansion of steam is effected by what is known as lap on the valve, the steam being cut off at the same point in each stroke, independent of load or pressure.

Riding cut-off is a term applied to cut-off valves which ride on the back of the main steam valve.

A "reversing" valve-gear is an arrangement employed for reversing the motion of engines. It is effected in different ways: in some cases with a single eccentric, while in others with two eccentrics, as in the case of the link; and in others still, by the means of a loose eccentric which revolves on the shaft, but is prevented from making a complete revolution by two stops so placed that one arrests it in the proper position for the forward, and the other for the backward motion. This last arrangement is peculiarly adapted to tug-boats and ferries, owing to the ease and quickness with which the engine can be reversed.

Q. 50. (1900-01.) What are "relief valves," "balance valves," "rotary valves" and "gridiron valves"?

Describe the plain slide valve and its action.

Why are plain slide valves not used in large engines and high pressures?

Ans. 50. Relief valves are used on the cylinders of large engines to prevent fracture of the cylinder-head and cylinder, in consequence of an accumulation of water in the latter. They are also used in many places for a relief from overpressure.

Balance-valves are arrangements by which the weight on the back of slide-valves, induced by the pressure of the steam, is relieved by the action of the steam in the steam-chest.

Rotary-valves is a term applied to any valve that describes a revolution in working.

Semi rotary-valves is a term applied to all valves that have a vibratory or rocking motion, similar to the Corliss.

Gridiron-valves are a modification of the slide-valve, containing a number of openings for the steam, by which means its travel and friction are materially diminished. Multi-ported valves.

The function of the common slide- valve is to admit steam to the piston at such times when its force can be usefully expended in propelling it, and to release it when its pressure in the cylinder is no longer required.

Owing to the amount of power expended in moving the valve in large engines and high pressures, the plain slide-valve is but little used.

Q. 51. (1900-01.) Define the terms "admission," "exhaust," "cut-off," "expansion," "compression," "angle of advance," "travel," "over travel," "inside lap," "outside lap," "steam lead," "exhaust lead," and "negative lead."

Ans. 51. Admission:—The period during which the steam passages are open and steam is admitted behind the piston.

Exhaust:—The period during which the exhaust passages are open and the steam is exhausted from the cylinder.

Cut-off:—The point in the stroke at which the steam-valve closes.

Expansion:—The period during which the steam expands in the cylinder, beginning at the point of cut-off and continuing until the steam is released or the exhaust port is opened.

Compression:—The period during which the steam is compressed, which is from the time the exhaust port closes until the end of the stroke.

Angular advance:—The angle which would be formed by the eccentric when in its actual position with the position of the eccentric corresponding to the central position of the valve, the crank being on its dead point.

Travel of the valve:—The total distance which the valve moves in one direction.

If the valve rod was of infinite length, this would be equal to twice the throw of the eccentric.

Overtravel:—Is the distance traveled by the valve over and above that necessary to fully open the steam port.

Lap on the valve:—The term lap on the valve denotes the amount the edges of the valve extend over the ports when the valve is in the center of its travel. The object of lap is to secure the benefit to be derived from the working of steam expansively.

Lap on the steam side of the valve is termed outside lap, while lap on the exhaust side is termed inside lap.

Steam lead:—Is the amount the port is open at the beginning of the stroke. The object of lead is to enable the steam to act as a cushion against the piston before it arrives at the end of the stroke, to cause it to reverse its motion easily and also to supply steam of full pressure to the piston the instant it passes the dead center. Generally the higher the speed and the more irregular the work, the more lead will be required for any engine.

Lead varies in different engines from 1-32 to 3-16 of an inch. Some valves have no lead at all, others less than none, or what is termed negative lead. Lead on the exhaust end means the amount of opening the valve has on the end from which the steam is escaping. The name applies alternately to each end of the cylinder.

Q. 52. (1900-01.) Given the throw of the eccentric, angle of advance and inside and outside lap. show how, by the "Zeuner diagram," the distribution of steam may be studied.

Ans. 52. Draw a line OX to represent the crank at the beginning of the stroke, and with this as a radius draw the crank circle XX^1, X^2, X^3, X^4. Suppose the crank to turn in the direction of the arrow.

Through the point O draw the line RR^1, making the angle R^1OY^1 equal to the angle of advance, and lay off the distances OR and OR^1 equal to the eccentricity or throw of the eccentric. On the lines OR and OR^1 as diameters draw the two circles ORCD and OER^1F.

With O as a center and a radius OA equal to the outside or steam lap draw a circle ACD, and similarly with a radius OB equal to the inside or exhaust lap draw a circle BEF. Through the point O and the intersections C, D, E and F draw the lines OX_1, OX_2, OX_3 and OX_4.

We are now able to take from the diagram all of the data necessary for a complete understanding of the distribution of steam in the cylinder:

OX_1 is the position of the crank when admission of steam takes place.

OX_2 is the position of the crank when cut-off takes place. Hence $X_1 OX_2$ is the angle traversed by the crank during the period of admission.

OX_3 is the position of crank when exhaust opens.

OX_4 is the position of crank when exhaust closes, hence X_3OX_4 is the angle traversed by the crank during the period of exhaust and

X_4OX_1 is the angle traversed by the crank during the period of compression.

The distances from the intersection of the circles R and R_1 with the lines OX_3 OX_1, etc., representing the crank in its different positions to the center, represent the travel of the valve corresponding to those positions of the crank.

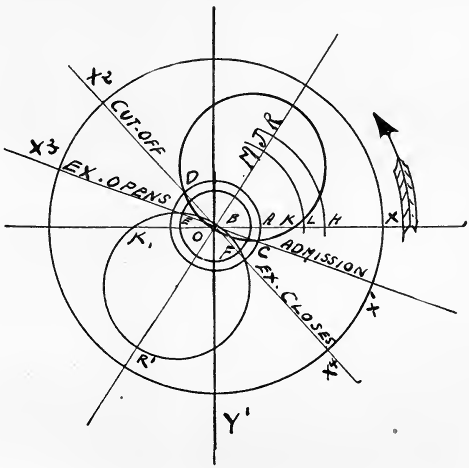
The circle R represents the forward and the circle R^1 the return stroke, hence OK is the distance the valve has traveled from its central position at the beginning of the stroke.

OK^1, the same for return stroke.

OA is the outside or steam lap, hence AK is the distance the steam port is open at the beginning of the stroke or steam lead.

OR is the full travel of the valve.

OB is the inside or exhaust lap, hence BK is the distance the exhaust port is open at the beginning of the stroke or the exhaust lead.



THE ZEUNER DIAGRAM.

At the points C and D the travel of the valve is just equal to the outside lap; hence in these positions of the crank the steam port opens and closes respectively; similarly at the points E and F the travel is just equal to the exhaust lap; hence in these positions of the crank the exhaust port opens and closes respectively.

If we lay down from the point A at a distance AH, equal to the width of the port, and with O as a center and a radius OH, draw an arc cutting the line OR, at J.

JR is the distance the valve travels more than enough to fully open the port, or the over-travel. Similarly if we lay off from B the dis-

tance BL, equal to the width of the port, and from the center O and a radius equal to OL draw an arc cutting OR at M, MR is the distance the valve travels more than enough to fully open the port for exhaust.

It will thus be seen that by a careful study of the diagram all information necessary for the proper design and setting of the valve gear may readily be had. For example, in the above diagram the cut-off takes place a little later than ¾ stroke. It is evident that if it is desired to have the cut-off take place earlier, say ½ stroke, it will be necessary for the outside lap circle ACD to intersect the valve circle R in the line YY^1. This may be accomplished by increasing the outside lap, by reducing the eccentricity, or by changing the angle of advance. However, any one of these changes would also effect the entire distribution, and it would probably be necessary to lay down several diagrams before the most advantageous dimensions could be obtained.

Q. 53. (1900-01.) Explain how the lap and lead may be determined without removing the cover to steam chest.

Describe the piston valve and state its advantages and disadvantages as compared to a plain side valve.

Ans. 53. Open the cylinder drain cocks and disconnect them from the drain-pipe, so that the steam may be seen and heard to issue from them. Or, open the holes made for the indicator, if there are any; then let in a little steam and turn the engine over by hand, and note the commencement and cessation of the flow of the steam, just when the steam is admitted and cut off. The point of cut-off can be most accurately ascertained by turning the engine backwards. The steam in this case will commence blowing at the same point of the stroke at which it would cease blowing when turning it forward; and, owing to the elasticity of the steam, the commencement of the issue is always more clearly defined than the cessation when the issuing orifice is small.

For the same reason, the point of admission can be most accurately located by turning the engine forward.

To determine the lead, having found the point of admission, make a mark on the valve-stem at a known distance from some fixed point, and another after the pin has reached the dead center; this will give the lead. If the admission forward takes place when the crank-pin is exactly on the dead center, there is no lead. Having obtained the lead and cut-off for both ends, the travel and length of the connection being known, a diagram may be constructed similar to the one in the previous question, which will give the lap and port openings.

To obviate the extreme amount of friction of the common slide-valve, especially those of large size, where high pressure is used, the piston-valve has been designed to overcome this difficulty, it being a perfectly balanced valve, and the only pressure on the seat is due simply to the weight of the valve. As usually constructed, the valve-chest is bushed, the bushing being accurately turned to form the valve-seat, and the valve is made tight by the use of piston rings, the same as steam pistons.

In the Armington and Sims type it will be seen that the steam enters the cylinder around the inside edge of the valve, and also through additional passage cut in the valve. In this way the effective opening of the port for a given travel is greatly increased. The exhaust takes place around the outside of the valve, so that in reality the inside is the steam lap and the outside is the exhaust lap opposite as in the case of the ordinary D-slide valve.

The principal objection to piston-valves is that the seat wears unevenly—that is, at the bottom only, and thus become leaky. However, the seat may be readily removed and replaced by a new one with little expense.

It is used in many of the best types of stationary high-speed engines, because it is simple, light and perfectly balanced. It is also much used in marine engines, especially for the high-pressure cylinders.

Q. 54. (1900-01.) What is meant by a poppet valve?

How is the lift determined?

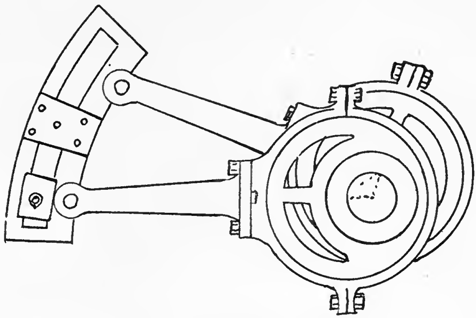
What is meant by a variable cut-off gear?

Explain the Stephenson link motion by the means of a sketch furnished.

Ans. 54. Poppet valves are those that open by rising from their seats. They are extensively used for the water distribution in pumps, and also in gas engines. In steam engines their use has been restricted to slow-running marine engines.

The lift of such valves, if single, would be about one-quarter of their diameter; if double, about one-eighth; in either case would give an area equal to the steam port.

Reversing the direction of motion of an engine is accomplished by a device, invented by Stephenson, by means of which the engine may be



THE STEPHENSON LINK.

not only reversed, but the cut-off raised to any desired extent in a very simple manner.

This is called the link motion.

It consists of two eccentrics, with straps and rods. The eccentrics are so placed that when one is in the right position for the engine to move forward, the other is in the position to run backwards. By raising or lowering the link, motion will be communicated to the valve and the engine will move forward or backward as the case may be.

The result of this combination is that the link receives a reciprocating motion in its center, since when one eccentric is moving the end of the link in one direction the other eccentric is moving the other end of the link in the other direction; so that the link will have nearly the same motion communicated to it as if it were suspended from a pivot at its center.

The horizontal motion communicated to the link by the joint action of the eccentrics is a minimum at the center of its length, which is equal to twice the linear advance and it increases towards its extremities, being nearly equal at either extremity to the motion which would be imparted to it by the eccentric at that extremity alone without regard to the other.

The valve rod is attached to a block which slides in the link, and the position of this block is varied by the means of a combination of rods and levers, attached in some cases to the block and in others to the link itself. In either case the link is suspended by a rod at some point, and the length of the rod, as well as the location of the point on the link to which it is attached, have an important influence on the motion of the link.

The travel of the valve depends upon the distance of the block from the center of the link. By moving the link up or down on the block or the block up or down in the link, the travel of the valve may be increased or diminished. The central position corresponds to no motion whatever, while the nearer the block is to either eccentric the more its motion will be under the control of that eccentric. Now, since the travel of the valve, other things being equal, determines the point of cut-off, it follows that the degree of expansion raises with the position of the block relative to the link.

In the sketch, for example, suppose the front eccentric is set for forward motion and the back eccentric for reverse motion. The link is suspended by a rod (not shown), and in the position represented in the sketch the block is at the top, and it is therefore entirely under control of the forward eccentric. Consequently the engine is going forward and the steam is cut off at the latest possible moment, the exact point of the stroke when the cut-off takes place depending on the lap and other dimensions of the valve gear. Now, as the link is raised the travel of the valve decreases and cut-off takes place earlier, until the block is in the center, when there is not enough travel to uncover the ports, and the engine comes to rest. It is obvious without further explanation that if the block is placed in the several positions controlled by the back eccentric that the effect will be the same, only in the reverse or opposite direction.

The term "full-gear forward" means that the link is dropped to its full extent; while "full-gear backward" means that the link is lifted to its full extent.

When the link-block stands directly under the saddle-plate both parts are closed, and neither admission nor exhaust can take place. The distance between the block and the end of the link when in full gear is termed the clearance.

The radius of the link is the distance from the center of the driving-axle or the shaft upon which the eccentric is located, to the center of the link, while the link itself is segment of the circle of that diameter. The length may be greater or less, but any variation from these proportions will give more lead at one end than at the other while working steam expansively, but the radius may be several inches shorter or longer without materially affecting the motion.

The vital point in designing a valve-link motion is the point of suspension of the link. If suspended from the center it will invariably cut off steam sooner in the forward stroke than in the backward stroke, while working expansively. It is customary to suspend the link at a point which is most used in the running of the engine.

The ease and facility with which the link may be handled is a very important feature in its favor.

Q. 55. (1900-01.) What is the function of a governor?

Explain the action of a single throttling governor. What are its principal defects?

In high speed machine why is the shaft governor used so extensively?

Explain the action of a single form of a fly-wheel governor?

Ans. 55. The function of a governor is to regulate or govern the speed of the engine, admitting the requisite amount of steam to do the work, sustaining the speed uniform or within a small percentage of it. The subject of regulating the speed of steam engines has of late years

received no little attention from engineers and practical inventors, and as a result various kinds of governors have been introduced.

Governors when attached to throttle-valves, work under circumstances that necessitate the use of openings for the passage of the steam that are too small in area, so much so that the useful effects of the steam are considerably diminished. On this depends the ill repute of throttling engines as compared with those which regulate with governor-controlled valve motions or variable cut-off.

If the valve of a governor has too large openings it will, owing to the unsteady action of the governor, admit too large a quantity of steam and cause a jumping of the engine; then in trying to shut off the extra amount it shuts it all off; in fact, the governor cannot fix it exactly right, being incapable of delicate changes.

This difficulty is best met by making the openings in the valve of peculiar shape, so that they open and close in a ratio different from that of the governor.

The principle of centrifugal force, as embodied in the old fly-ball governor of Watt, has been more resorted to than any other; but, aside from this, the governor has been so improved, altered, and reconstructed since his time as to be almost unrecognizable; but still the old principle remains, and also the prominent defects which so materially interfere with its efficiency.

The principal defects are three (3) in number. First is the friction which arises from the joints; second, defect is due to the fact that the balls as they assume different positions in keeping with the speed with which they revolve are obliged to rise and fall. This is necessary in order that the resistance which the weights offer to centrifugal force should constantly increase. If it did not so increase, the weights, when once started from their position of rest, would instantly go to the extreme limit of motion. The rising of the balls shortens the distance which they are allowed to move for a given variation by bringing the centers of the balls and arms on which they swing into a straight line, so that a variation which moves the balls a given distance upward, if it occurs again, will not move them nearly so far in the same direction. Again, the same force that would support the balls in any plane would not raise them to that plane from a lower one. So between friction, which destroys the delicate power that the balls assume under a slight change, and the necessity for a large change to overcome their inertia, it is almost impossible to obtain a degree of regulation which would be equal to all requirements.

The third defect in governors on throttling engines is that the valve stem has of necessity to pass through steam-tight packing boxes. There is also friction on the governor valve necessary to overcome the power required to move the valve-stem through all its bearings, guides, stuffing-boxes, etc., under the pressure of steam.

Were it possible to construct a governor for throttling engines which would approach in practice what theory would demonstrate the fly-ball or centrifugal governor would be a perfect regulator; but this appears under mechanical laws impossible.

By the use of insochronous governors, which would not admit of any variation of speed, but would be in equilibrium at any speed, whether the balls were up or down or in any other position, the defects of the common governor were supposed to be obviated; but it was found by experience that power and stability were necessary, and isochronism in its strict sense unattainable.

In the fly-wheel governor these defects have been partially eliminated, and it has been found that much closer regulation is attainable with the aid of governors of this class and also that there is less variation of speed during each single stroke.

For these reasons nearly all modern steam engines, excepting the roughest type, are equipped with governors which act upon the cut-off. It will be readily understood that the tension of the springs and the

weights may be so adjusted as to maintain a position of equilibrium and thus produce an approximately uniform speed of rotation. With the aid of a well-designed governor of this type it is possible to regulate the engine to within 1 per cent of its rated speed from full load to no load or no load to full load.

The action of the fly-wheel governor, which is the type used on most high-speed engines, may be described as follows:

The arms carrying weights are pivoted to the fly-wheel and springs are attached to these arms and the rim of the wheel, the links connecting the arms and collar, which is placed loosely on the main shaft, which carries the eccentric. When the fly-wheel revolves there is a tendency for the weights to travel outward—that is, away from the shaft—and the centrifugal force which actuates to move in that direction is counteracted by the tension of the springs. If the speed increases this tension is partially overcome and the weights move outward, and in so doing shift the eccentric and changing its eccentricity, angle of advance, or both, and thus produce an earlier cut-off in the cylinder, or, as the case may be, this operation may be reversed and a later cut-off take place.

Governors should be kept perfectly clean and free from accumulations induced by the use of inferior oils, as such gummy substances have a tendency to interfere with the easy movement of the different parts; parts working through packings should be frequently packed, that the packing may be kept soft.

Q. 56. (1900-01.) What is the effect on the steam distribution if the cut-off is varied by altering the angular advance only or the eccentricity only?

In what form of valve gear is it not necessary to vary both the angular advance and the throw of the eccentric?

Ans. 56. In the case of a single valve operated by a shaft governor, if the angle of advance only is altered, the cut-off may be varied to suit the conditions of load, but in that case the lead will also vary in such a way that it would increase as the cut-off decreased. If, on the other hand, the regulation is performed by varying the eccentricity alone, the reverse would take place, and hence for shaft regulation in connection with a single valve it becomes necessary to vary the eccentricity and angle of advance simultaneously.

This is not the case where separate distribution and expansion valves are used, as in the "Buckeye Engine," because the admission and exhaust closure are affected by the distribution valve, and the governor acts only on the cut-off.

Q. 57. (1900-01.) How would you calculate the diameter of governor pulleys?

What is the maximum variation in speed allowable with a good shaft governor?

Explain the action of the governor in the Corliss type of engines.

Why can Corliss engines not operate at a high rotative speed?

Ans. 57. To find the diameter of the governor shaft-pulley—

Multiply the number of the revolutions of the engine by the diameter of the engine shaft pulley and divide the product by the number of revolutions of the governor.

To find the diameter of the engine shaft pulley—

Multiply the number of revolutions of the governor by the diameter of the governor shaft pulley and divide the product by the number of revolutions of the engine.

The maximum variation in speed in the modern first-class high-speed engines should not exceed more than 2 per cent. Many engines are guaranteed that from full load to no load the variation will not exceed 1 per cent.

In Corliss engines the economy in the use of steam and the close regulation which has been attained certainly makes this class of engines very desirable for a great many purposes.

Owing to the method of effecting the cut-off they are, however, limited as to speed of rotation, and it is consequently customary to secure the advantages which are to be derived from high-piston speeds by making the stroke very long. Of course, this renders them unfit for direct coupling to electrical and other machinery which needs to run at a comparatively great number of revolutions per minute, but there are many other uses to which the Corliss can be put to advantage.

Q. 58. (1900-01.) What are the characteristics of high speed automatic cut-off engines?

For what class of service are they especially adapted? Why?

What is the steam consumption per horse-power in this class of engine?

Ans. 58. The class of engines known as the high-speed automatic cut-off type, which now comprise a large variety of designs, owes its development largely to the unusual growth of electric lighting and power, isolated plants and electric railway service. Engines of this class, while applicable under various conditions, are designed primarily to meet the requirements which the nature of this service imposes.

An engine used for driving a lighting or power generator is constantly subjected to sudden, and very often considerable, variations of load, and must under these circumstances maintain a constant or nearly constant speed. It must also be economical in the use of steam, run at a comparatively high rotary speed, and be simple in design. In general, these, briefly, are the conditions which have evolved the high-speed automatic cut-off engine, these engines, while not so economical in the use of steam as the Corliss type, are vastly better than the old throttling engines. They consume from thirty to thirty-five pounds of steam per horse-power hour, when operating under an initial pressure of eighty pounds and cutting off at one-quarter stroke, while where compounded, which is frequently done, their steam consumption is about twenty-five pounds.

Q. 59. (1900-01.) Explain what is meant by a "four-valve" engine, and why it is more economical than a single-valve engine?

What are the advantages and disadvantages of single-acting engines?

Ans. 59. The four-valve engine is a type which has been designed to combine some of the principal advantages of the Corliss type and the high-speed engines. It resembles the high-speed type in that the cut-off is varied to meet the changes in load by means of a shaft governor, and it resembles the Corliss engine in having separate passages for the admission and the exhaust, thus avoiding the losses inherent in single-valve engines and at the same time retaining the advantages to be derived from high rotative speed, which may be had on account of the absence of the releasing mechanism.

There being separate parts for admission and exhaust, the fresh steam does not come in contact with the surfaces which have been previously cooled by the exhaust, hence the condensation of the steam is reduced to the minimum.

Some of the advantages of the single-acting engine are high rotative speed, simplicity of design and the economy that has been obtained in steam consumption.

The results which are attained in this respect are due to high speed, multiple expansion, quick cut-off and short steam passages. The lim-

ited amount of floor space occupied makes its application very desirable where the available space is limited. The two principal designs of this class of engines are the "Willans" and the Westinghouse.

These engines are well adapted for a variety of uses. They are especially valuable in location where the engine is exposed to dust, since the working parts are almost completely enclosed in the casing. The high speed and close regulation make it useful also for electric lighting and railway service, although it is not nearly so economical in the use of steam as many other types of engines.

Q. 60. (1900-01.) What are the most frequent causes of knocking in steam engines?

How may knocks be located?

What are the remedies for different kinds of knocks?

Explain how an engine with a fixed eccentric may be reversed.

Ans. 60. The most frequent cause of knocking in steam engines are lost motion in the cross-head, wrist and crank pin boxes, looseness in the pillow-block or main bearing boxes, looseness of the piston rod or follower-plate, the crank pin or crank shaft being out of line with the cylinder or the wrist pin, crank pin or main bearing journal being worn oval; the slide valve having too much lead or not enough; the exhaust opening being too soon or too late; the valve being badly proportioned or the exhaust passage outside of the cylinder being contracted.

Other causes are shoulders being worn in each end of the cylinder, in consequence of packing rings not traveling over the counter-bore at each end of the stroke; or shoulders being worn on the guides, resulting from cross-head shoes not overlapping them when the crank is on the dead center; the piston not having sufficient clearance at either end of the cylinder, in consequence of its being altered by taking up the lost motion in the boxes; there not being sufficient draught in the keys to take up the lost motion in connecting-rod boxes; the packing being screwed too tight round the piston-rod; excessive cushioning, resulting from the leaky condition of the piston, which allows the steam to occupy the space between the cylinder and piston-head, as the crank approaches the center, thereby subjecting the engine to an enormous strain, as at this part of the stroke the fly-wheel is traveling very fast and the crank moving very slowly; lost motion in the connection by which the slide-valve is attached to the rod.

Engines out of line frequently knock sideways at the half-stroke, but most generally at the outward and inward upper or lower dead center, as these are the points that the greatest strain is thrown on the bearings in consequence of the direction of the connecting-rod having to be reversed. The foregoing causes of knocking in engines constitute the principal ones.

Knocks arising from lost motion in any of the revolving, reciprocating or vibrating parts of an engine may be located by placing the fingers on the part, while the cross-head is being moved back and forth on the guides by the starting bar; but knocks induced by the valve opeing or closing too soon, by the contraction of the exhaust, or by the valves being improperly set, are the most difficult to discover, as they are different from those induced by lost motion, the sound being a dull, heavy thud in many instances, causing the engine, building, and even the foundation to vibrate at each stroke.

While an intelligent and careful search will in most cases result in successfully locating the knock, some will for a time baffle the most expert engineer. There are instances where the indicator has been applied in order to determine the precise location of the knock or thud.

Remedies for knocking in steam engines: While it is possible in most cases to locate the knocking, it is hardly possible to prescribe a remedy for all, as in many instances it must arise out of and be determined by circumstances of the individual case.

The most practical method of remedying the knocking induced by the crank-pin being out of line, is to place the crank-shaft at right angles with the center of the cylinder, remove the old crank-pin, rebore the hole so as to bring the center of the new pin perfectly in line with the axis of the cylinder, and replace the old pin with a new one.

The knocking induced by the wrist-pin and crank-pin becoming worn oval, may be remedied by filing them perfectly round; but the knocking caused by the crank-shaft journal being worn out of round is very difficult to remedy; in fact, there is no remedy for it except remove the shaft, true it up in a lathe and refit the boxes; this operation is attended with considerable difficulty, more especially when the engine is large.

Knocking in boxes on the crank-pin and cross-head or valve rod may be remedied by refitting the boxes, readjusting the keys or by putting a liner behind or in front of the boxes when there is not sufficient draught in the keys and gibs.

Knocking in the steam-chest caused by looseness in valve connections may be remedied by readjusting the jam-nuts or the yoke. Knocking arising from this cause manifests itself more frequently when the steam is shut off from the cylinder, preparatory to stopping the engine, than when the engine is running; the lost motion is taken up in the valve connections by the pressure of the steam on the back of the valve.

Knocking in the piston is generally caused by the rod becoming loose in the head, and if it continues for any length of time it destroys the fit of the rod in the hole.

The only practical remedy is to remove the rod, rebore the hole, bush it or thicken the rod at that point by welding, and fit to the head after the hole is rebored perfectly true.

Knocking in follower-plate is generally caused by bolts being too long or from dust allowed to accumulate in the holes, which prevents them from entering sufficiently far to take up the lost motion in the plate. Remedied by cleaning out the holes or shortening the bolts.

Knocking caused by shoulders becoming worn in cylinders at each end can be remedied by reboring the cylinder, making the counterbore sufficiently deep that a part of one of the rings will overlap it at each end of the stroke.

Shoulders worn on guides can be remedied by planing the guides and making the shoes sufficiently long that they will overrun the guides when the crank is at either center.

The knocking induced by any of the foregoing causes is generally a source of great annoyance, as any attempt to adjust the boxes on cross-head or crank-pin or the piston-packing in cylinder generally aggravates the cause of the knocking, as any adjustment of the connecting rod boxes alters the position of the piston in cylinder and the cross-head on guides, and causes them to strike harder against the shoulders.

Knocking caused by the valve or valves being improperly set may be remedied by removing the bonnet of steam-chest and adjusting the valve, so that it may move uniformly on its seat, thereby giving the valve the same and proper amount of lead at each end of the stroke; then if the valve is well proportioned and the connections thoroughly fitted and skillfully adjusted there is no reason why the engine should knock from this cause.

The knocks arising from bad proportion in the valves and steam passages are the most difficult of all to remedy, as they are inherent in the machine.

How to reverse an engine:

Place the crank on the dead center and remove the bonnet from the

steam chest; observe the amount of lead or opening that the valve has on the steam end; then loosen the eccentric and turn it around on the main shaft in the direction in which it is intended the engine should run until the valve has the same amount of lead on the other end. The engine should then be turned on the other center for the purpose of equalizing the lead; the crank should also be placed half-stroke, top and bottom, for the purpose of determining whether the part opening is the same in both positions.When the crank is half-stroke the center of crank-pin is plump with the center of crank-shaft.

Pumps, Compressors, Hydraulics, Refrigeration, Heaters, Condensers, Injectors, Etc.

Q. 8. (1896-7.) How to properly set duplex steam pump valves?

Ans. 8. Place steam pistons in the center of their travel, which will bring the rocker arms perpendicular to rods. Place slide valve over center of steam ports. The lost motion in pumps of small size that usually have non-adjustable blocks, on valve stems, should measure the same on each side of blocks, between valve lugs. If lost motion is equal the valves are set. Move one valve so as to admit steam before putting on steam chest covers. On the medium and larger sizes, where adjustable locknuts are used on valve stems, there are no fixed rules for the exact amount of lost motion, which governs the length of stroke, and this can only be determined satisfactorily by trial and careful adjustment. In the large pumps with the outside slotted link and sliding block, where the valve movement is coincident in time and amount to valve rod movement the distance from each end of link block to each end of link slot should measure the same when slide valves are central over ports.

Q. 9. (1896-7.) HP. required to raise 300 tons water 150 ft. in one and one-half hours, barring friction?

Ans. 9. 300 (tons) $\times$ 2,000 (lbs.) $\times$ 150 (ft.) $\div$ 1.5 (hours) $\div$ 60 (min.) $\div$ 33,000 (ft. lbs.) $=$ 30 10/33 HP.

Q. 12. (1896-7.) How to find steam cylinder diameter for direct acting boiler feed pump?

Ans. 12. Find the maximum amount of water required. Find the size of the plunger that will displace this amount of water at a fair piston speed and make the steam end 2¼ times the area of the water end. [Pump cylinder should allow 2% to 15% for slip.]

Q. 13. (1896-7.) How many tons of ice (spec. gr. .9188) to fill a room 15 ft. $\times$ 16 ft. $\times$ 10 ft.?

Ans. 13. 15 (ft.) $\times$ 16 (ft.) $\times$ 10 (ft.) $\times$ 62.5 (lbs.) $\times$ .9188 (spec. grav.) $\div$ 2,000 (lbs.), $=$ 68.91 (tons). [Ice should be packed with 1″ strips of wood between, hence allowance must be made for the strips.]

Q. 16. (1896-7.) What is efficiency of direct acting steam pump from coal in furnace?

Ans. 16. A direct acting steam pump requires about 120 lbs. steam per hour per HP. Assuming that the boiler evaporates 10 lbs. of water per pound of coal there would be 12 lbs. coal used per HP. per hour.

The number of foot pounds used per hour in the furnace would be 13,000 $\times$ 778 $\times$ 12, assuming the value of each pound of coal to be 13,000 heat units. This divided by 60 would give the heat units used per minute and this result multiplied by 100 and divided into 33,000 would give the percentage of efficiency.

$= 1.66\ \%$ efficiency.

Q. 30. (1896-7.) What is the cause of water hammer in the discharge pipes of pumps, and how is it avoided?

Ans. 30. The inertia of the water, which, when in motion, tends to continue in motion, after the impelling force has ceased to act and its energy of motion is expended in giving a blow to the containing p pe. Any means which will induce an uninterrupted flow, or which will bring the water gradually to rest, will prevent water hammer.

The first result can be obtained by the use of a large air chamber, or, in the case of a duplex pump, by adjusting the steam valves so that one piston begins its stroke before the other has stopped.

The second result (gradually checking the flow) can be secured by placing an air chamber on the discharge pipe near the end at the pump or by having the pump cushion in such a manner as to bring the piston gradually to rest and not keep up its speed to the extreme end of the stroke and then abruptly stop.

The admission of air with the water entering will, in some cases, prevent the trouble and a small snifting valve, opening inward, placed on the suction pipe near the pump, will in case the discharge pressure is low, sometimes stop the hammer.

Q. 48. (1896-7.) What is the most economical for feeding boilers, a direct acting pump, a power pump, or an injector? Has one any advantage over the others under certain conditions? If so, when and how?

Ans. 48. In cases where the exhaust from engines can be utilized for heating the feed water the injector cannot be used with economy, because, first, if an open heater is used the injector will not take the water; second, if a closed heater is used the feed will not take up much of the heat in the exhaust steam for the reason that the feed water, after passing through the injector, is nearly as hot as the exhaust steam itself.

A power pump driven by a belt from the shafting is more economical as a boiler feeder than either a direct acting pump or an injector. It has, however, this disadvantage, that the shaft must run in order to get water into the boiler. On account of this it is not generally used.

The direct acting steam pump, while it is not as economical as the power pump, is independent of the engine, and can be placed in any part of the boiler or engine room, and is ready to start as soon as there are a few pounds pressure of steam in the boiler.

The injector, while it is still less economical than either the power pump or direct acting pump, is, in cases where the feed water is cold and no waste heat is available for heating it, preferable and more economical than either the steam pump or power pump, first, because it furnishes hot feed water for the boiler, and, second, because the injector, taken as a pump and feed water heater, has a very high efficiency. But, all things taken into account, we consider the direct acting steam pump the most economical method of feeding boilers.

Q. 54. (1896-7.) How do we find the amount of injection water required per HP per hour?

Ans. 54. The amount of injection water required per indicated horse-power will depend upon, first, the temperature of the injections; second, the economy of the engine; third, the final temperature of the hot well. The unit of water required per unit of steam condensed can be found by the following formula:

Let I = temperature of injection.
Let D = temperature of discharge.
Let S = total heat of steam discharged at release.

$$\frac{S-D}{D-I} = \text{lbs. of water per lb. of steam condensed.}$$

Example: Temperature of injection, 60°; temperature of discharge, 120°; total heat above 32° in 1 lb. of steam of 20 lbs. pressure equals 1150 units; then—

$$\frac{1150-120}{120-60} = \frac{1030}{60} = 17.16 \text{ lbs. water per pound of steam condensed.}$$

If 20 lbs. of steam are used per horse-power per hour, then $20 \times 17.16 = 343.20$ lbs. of water used per HP per hour.

This amount increases with temperature of injection and inversely with the temperature of the discharge.

Q. 81. (1896-7.) A pumping engine works against a gage pressure of 43.4 lbs., and a vacuum of 25″ is needed to raise water to the pump: What will be the total height in feet against which the pump works?

Ans. 81. No temperature being given, we will assume that 1 ft. of water exerts a pressure of .434 lbs. per sq. in., also that 1″ mercury equals 1.133 ft. of water, then:

$\frac{43.4}{.434} = 100$ ft. on discharge side and 1.133×25 inches vacuum $= 28.325$ ft. on suction side, or

$$\frac{43.4}{.434} + [1.133 \times 25] = 128.325 \text{ ft.}$$

Q. 91. (1896-7.) An air compressor takes air at atmospheric pressure (15 lbs.) and 60° F., and compresses same adiabatically to 120 lbs. gage pressure. Find the temperature at the end of compression. The ratio of relative specific heats is 1.4.

Ans. 91. T^1 = absol. temp. after compression.
T = absol. temp. before compression, or 460° + 60° = 520°.
P^1 = absol. pressure after compression, 120 + 15 = 135 lbs.
P = absol. pressure before compression = 15 lbs.

$$\frac{T^1}{T} = \left(\frac{P^1}{P}\right)^{.29} \text{ or } T_1 = T\left(\frac{P^1}{P}\right)^{.29} = T^1 = 520\left(\frac{135}{15}\right)^{.29} = 520 \times 9.^{29}$$

log 9 = .954243 × .29 = .276731 representing 1.8915: 520 × 1.8915 = 983.32, total tempr., less 460 = 523.3°.

Q. 94. (1896-7.) Given a piston force pump with a lever of the second order, having a 2″ piston and a ram with 25″ diameter, pump lever is 5″ from fulcrum to center of piston, and 60″ from center of piston to end of lever: How much weight needed on end of lever, to equalize a load of 100,000 lbs. on the ram, ignoring friction or weight of parts?

Ans. 94. $25^2 \times .7854 = 490.8$ sq. in. area of ram.
$2^2 \times .7854 = 3.1416$ sq. in. area of piston.

$$\frac{100{,}000 \text{ lbs.}}{490.8} = 203.72 \text{ lbs. pressure on each inch of ram and piston.}$$

$3.1416 \times 203.72 = 640.07$ lbs. total pressure on piston.

$$\therefore \frac{640.07 \times 5}{65} = 49.23 \text{ lbs., or say 50 lbs.}$$

Or a shorter method: $25^2 = 625$, $2^2 = 4$.

$$\frac{100{,}000}{625} = 160. \quad 160 \times 4 = 640. \quad \frac{640 \times 5}{65} = 49.23 +$$

Q. 100. (1896-7.) In a refrigerating plant it is required to find the thermal units of refrigeration and of condensation, also the efficiency of compression, the specific heat of the liquid being 1.08, when the inferior absolute pressure (suction pressure) of the ammonia is 40 lbs. to the square inch. The temperature when it enters the compressor is 25° F. and it is compressed to 165 lbs. per square inch absolute without superheating, then condensed into a liquid of 85° F., then admitted to the cooling coils evaporated, and heated to the initial state.

Ans. 100:

Temperature absolute at 40 lbs.	$r_2 = 472$
Temperature of liquid 472-460	$T_2 = 12$
Absol. tempr. of saturation 460+25	$r = 485$
Superheating	$r - r_2 = 13$
Absol. tempr. at end of compression	$r_1 = 545$
Absol. tempr. of saturation 460 + 25	$r = 485$
Temperature of liquid at p_1	$T_1 = 85$
Fall of tempr. from T_1 to T_2	$T_1 - T_2 = 73$
Heat absorbed during this fall 1.08×73	$= 78.84$
Latent heat of evaporation at T_2	$h = 548$
Condenser heat removed	$h_1 = 502$
Refrigeration per lb. of ammonia $548 + (13 \times 0.508) - 78.84$	$h_2 = 475.76$
Efficiency $\dfrac{h_2}{h_1 - h_2}$	$E = 18.13$

That is, for every thermal unit of work done by the compressor 18.13 thermal units will be removed from the cold room. The efficiency of a compressor is greatest when the difference between the inferior and superior temperature (r_1 to r_2) is the smallest.

Q. 38. (1897-8.) What is the greatest height to which a pump may draw water that is at a temperature of 191° F.?

Ans. 38. The pressure of the atmosphere is about 14.7 lbs. per square inch. The pressure of steam at 190° is about 9.5 lbs. per square inch. There could never be a vacuum less than the pressure of the steam. So that the pressure possibly available to raise the water is $14.7 - 9.5 = 5.2$ lbs. per square inch. This corresponds to

$$\frac{5.2}{.434} = 12 \text{ ft.}$$

nearly. (See No. 28 of last year's questions.)

Q. 39. (1897-8.) What effect will the required velocity of the water in the inlet pipe to the pump have on the height to which the water may be raised, neglecting the friction of the water on the pipe?

Ans. 39. It will lessen the height by an amount equal to the "head" required to give it the velocity. This head would be about equal to the square of the velocity (in feet per second), divided by 64.

$$h = \frac{V^2}{64.} +$$

A number have answered No. 39 by saying that the velocity of the water in the inlet pipe would have practically no effect upon the height to which the water could be drawn. This is no doubt so if the velocity of the water is small and regular. Nevertheless we believe that very often when a pump fails to take water for its entire stroke the reason is to be found in the inertia of the water entering the inlet pipe. [Air in water and the vapor of water produced by the vacuum, as well as slip of valves, all tend to prevent the cylinder from filling.—Ed.]

Q. 29. (1898-9.) Define units of ice making and refrigerating capacity.

Ans. 29. In refrigeration, an effect equivalent to the conversion of 2,000 pounds of water at 32° into a ton of ice at 32°; that is, the abstraction of 284,000 B. T. U. is considered a "ton," the latter word in this sense being a unit expressive of the duty just described.

Q. 102. (1898-9.) Give the piston speed you consider best adapted for boiler-feed pump, when same is supplying a "continuous" feed.

Ans. 102. A desirable piston speed for boiler feed pump when supplying a continuous feed approximates 50 ft. per minute.

Q. 103. (1898-9.) Name the type of pump and dimensions necessary to supply the boilers referred to in Q. 93.

Ans. 103. Dimensions of feed pump for boilers referred to in Ans. No. 93 may be determined as follows:

Figuring on 200 HP as the normal demand on boilers but providing 50% for overload = 300 HP.

Allowing 30 lbs. water per HP plus 25% for non-efficiency of pump over its nominal displacement, gives 40 lbs.

Or $\frac{300 \times 40}{60} = 200$ lbs. of feed water to be "moved" per minute.

Assuming 50 ft. of piston travel as per Ans. No. 102 we have $200 \div 50 = 4$ lbs. or ½ gallon as the required displacement per foot of piston travel and which is equivalent to 3½" dia. plunger for single cylinder or 2½" dia. for double cylinder pump. Stroke of pump may be any length common to the trade, for the given diameters.

If conditions permitted a power pump, one of the "triple" type, would be preferred.

The independent steam pump has an "emergency reserve," which is equal to any margin of speed that can be properly attained above the 50 ft. which is usually figured on. When the limit of speed in a power pump is fixed in its driving mechanism, such a reserve is not available and for that reason their capacity should be somewhat greater than figured for the steam pump.

Power pumps may be kept in constant motion and arranged to supply either a constant or variable feed by providing a suitable "by-pass" arrangement.

Q. 104. (1898-9.) What would probably be the size of the pipe connections on any standard injector, capable of supplying boilers of 200 HP?

Ans. 104. 1¼″ would be the minimum size for the injector-pipe connections for the duty referred to in this question.

Q. 105. (1898-9.) Explain the general features claimed for open and closed feed-water heaters.

Ans. 105. Feed-water heaters tend to economy and obviate strains caused by forcing cold water into hot boilers. Ordinarily the saving of fuel amounts to about 1% for every 11° of temperature added to the "feed" by the heater.

Heaters of the "open" type are preferable for waters that will precipitate solid matter at temperatures near the boiling point. Well constructed heaters of this style heat the feed water very efficiently; they intercept large quantities of "scale" making matter which is an especial advantage with certain waters. They can also be thoroughly inspected and cleaned when necessary. The exhaust, mingling with the feed water condenses a percentage of the steam but also causes oils from cylinder lubrication to become mixed with the feed.

The mixing of the oil and the further disadvantage of pumping hot water do not obtain with "closed" heaters, but as both of these so-called "difficulties" which attend open heaters are readily overcome they are very much in vogue, for the reasons which are noted.

Q. 67. (1899-1900.) What is the force against which a pump works, aside from boiler pressure?

Ans. 67. Gravity, or the attraction of the earth, which prevents the water from being lifted. This is shown in the fact that water can be led, or trailed, an immense distance, limited only by the friction of the pump.

Q. 68. (1899-1900.) In designing or purchasing a pump, what is a safe rule as to capacity?

Ans. 68. One should be selected capable of delivering 1 cu. ft. of water per H.P. per hour; or, in other words, about 3 lbs. of water for each sq. ft. of heating surface.

Q. 69. (1899-1900.) What is the most necessary condition for the satisfactory operation of a pump? What is the advantage of a suction chamber? What should long suction pipes be provided with?

Ans. 69. A full and steady supply of water. The pipe connections should in no case be smaller than the openings in the pump, and the suction lift and delivery pipe should be as straight and smooth on the inside as possible.

A suction chamber (air) eliminates pounding, makes the action of the pump easy and uniform, also facilitates the filling of the barrel of the pump when at high speed.

Long suction pipes should be provided with a foot-valve just above the strainer in the well or pit.

Q. 70. (1899-1900.) For boiler feed pumps, or pumps doing a similar duty, approximately what is the proportional area of the steam to the water cylinder?

Ans. 70. The steam piston should have about 2¾ times the area of the water piston. There being no mechanical purchase in favor of the steam piston, it must have the greater area of the two in order to overbalance the pressure on the water piston

Q. 71. (1899-1900.) What is the rule for finding the quantity of water, in gallons, pumped in one minute, at 100 piston ft. per minute?

Ans. 71. The diameter, in inches, squared, and multiplied by 4, equals the required amount of water in gallons.

$4D^2 =$ number of gallons.

Q. 72. (1899-1900.) How do you find the H.P. necessary to pump water to a given height? How many H.P. are required to pump (10,000,000) ten million gallons of water (150) one hundred and fifty ft. high in (10) ten hours, slippage and friction not taken into account?

Ans. 72. Multiply the total weight of the water in pounds by the height in feet, and divide the product by 33000.

10,000,000 gals. pumped in 10 hours.
1,000,000 gals. pumped in 1 hour.
16.666 gals. pumped in 1 minute.
$16.666 \times 8\frac{1}{3} = 138,883$ lbs. in one minute.

$$\frac{138,883 \times 150}{33,000} = 631.3 \text{ H.P.}$$

Q. 73. (1899-1900.) What have you to say in regard to friction and slippage in well designed and constructed pumps?

Ans. 73. In well-designed and properly constructed steam pumps the slippage will amount to about 10 % of water pumped, and an allowance of 25 % would be a fair allowance for both the slippage and the friction of the pump.

In old or badly constructed pumps, working against a very high pressure, or a very low lift, the net loss would be increased to twice the percentage given; so that, in calculating the size of a feed pump, allowing for leakage of water, priming of the steam, blowing off and all other leaks that may occur. For a steam engine the pump should have the capacity of 2 to 2½ times the net quantity of feed water required for the work of the engine.

For marine engines, liable to use salt water, the size of the pump should be so as to be able to deliver from 3 to 4 times as much.

Q. 74. (1899-1900.) From what is power developed in forcing water into a boiler by an injector? Approximately, what is the difference in the velocity of the steam and the water?

Ans. 74. From the difference in the velocity of the escaping steam from a boiler under pressure, and the velocity acquired by water from the same boiler, and under the same pressure, and at the same time.

Approximately, the steam has a velocity of 16 to 18 times that of the water, varying with the different pressures.

Q. 76. (1899-1900.) Give rule for finding the saving which may be expected by heating the feed water a given amount.

What percentage of the saving of fuel may be expected by heating feed water from 60° to 200° for a boiler carrying 125 lbs. gauge pressure of steam?

Ans. 76. Divide the difference in the total heat of the water above 32° F., before and after heating, by the total heat required to convert it into steam from the given initial temperature; multiply this quotient by 100, and the product will be the percentage of saving to be expected.

Water at 200° contains above 32°, 168.70 B.T.U.
Water at 60° contains above 32°, 28.01 B.T.U.

168.70 — 28.01 = 140.69 = the number of heat units between the two temperatures of the water (60° and 200°).

There is in steam, at 125 gauge pressure, 1189.5 B.T.U. above 32° F. or 1189.5 — 28.01 = 1161.49 B.T.U. above 60° F.

This is the amount of heat that the boiler would have to supply to make a pound of steam from the given initial temperature of 60° F.; but we have seen that in raising the water to 200° F. 140.69 units are supplied by the heater, thus saving 140.69 ÷ 1161.49 of the heat required.

140.69 × 100 ÷ 1161.49 = 12.1 %, the percentage of saving to be expected.

The same result may be found from the use of the table showing the increase of temperature for each degree of initial temperature and steam pressure; thus, in the column of 60° and the pressure column of 125 lbs. we find the increase .0861, the saving for each degree; hence .0861 × 140 = 12.054 or 12.1%.

Q. 100. (1899-1900.) With an engine exhausting into a surface condenser, 1,145 lbs. of steam, requiring 21,526 lbs. of water for condensation of the steam, the pressure of the steam entering the condenser is 4 lbs. absolute per square inch, the condensing water entering the condenser at temperature of 60° F., discharging at 115° F., what was the temperature of the condensation? How many inches of vacuum was being maintained?

Ans. 100. Difference in temperature of the entering and the discharged water equals 115° F.— 60° F. = 55° F.

The B. T. U. in water at a temperature of 115° F. = 83.129. The B. T. U. in water at a temperature of 60° F. = 28.009; hence—

The number of heat units that the water will absorb in changing from a temperature of 60° F. to a temperature of 115° F. equals 83.129 — 28.009 = 55.12 B. T. U.

The total weight of the water used 21526 lbs. The total weight of the steam condensed 1145 lbs.

Each pound of steam condensed requires as many pounds of water as 1145 is contained in 21526.

21526 ÷ 1145 = 18.80, equals the number of pounds of water required to condense one pound of the steam.

One pound of water absorbs 55.12 B. T. U. Then 18.80 lbs. water will absorb 18.80 times 55.12 B. T. U.

18.80 × 55.12 = 1036.256 B. T. U. equals the number of heat units absorbed in condensing 1 pound of the steam.

One pound of steam at 4 lbs. absolute pressure contains a total heat of 1128.6 B. T. U. above 32° F., so that the total heat equals 1128.6 added to 32, 1128.6 + 32 = 1160.6 B. T. U.

If the water absorbs 1036.256 B. T. U. in condensing one pound of steam then it must leave in the condenser a temperature equal to the difference between 1160.6 and 1036.256.

1160.6 — 1036.256 = 124.344 B. T. U. = equiv. temp. 124.04° F., sustaining a vacuum of about 26.4 inches.

In practice this will be some less for the reason that the air gets into the condenser and the pressure will be higher than that due to the temperature. For this reason it is common to see condensers with a discharge temperature of 100° F., which by the tables should give a vacuum of 28 inches and over, while the gage shows but 26 inches and even less.

Q. 101. (1899-1900.) Describe a surface condenser. Describe a jet condenser. Which requires the greater amount of water for condensation purposes? In selecting a type of condenser what conditions existing would govern the choice between the two types of condensers?

Ans. 101. A surface condenser is a vessel, or a receptacle, constructed in various shapes, with double heads at each end.

The space between the inner heads is filled with small brass tubes varying in sizes in different constructions from ½ inch to 1 inch diameter.

In some constructions the tubes are made fast in one tube sheet and in the other tube sheet made secure by means of stuffing box and gland.

In some constructions they are made secure by stuffing box and gland at both ends.

Some constructions the tubes are made fast in each tube sheet and corrugated their entire length.

These different precautions are taken for an allowance of expansion and contraction due to the different temperatures to which they are subjected.

The steam is usually passed through the annular space surrounding the tubes and the water forced through the tubes, although a "vice versa" process is allowable and is sometimes practiced.

The steam from the exhaust of the engine coming in contact with the cool surfaces of the tubes, is condensed and falls to the bottom of the condenser, causing a partial vacuum, and is removed by the means of an air pump, the same pump also performing the duty of removing any air that may enter the condenser.

The circulation of water in the tubes is usually kept up to a normal speed per minute by the means of a circulating pump.

Two pumps are generally used with a surface condenser.

The jet condenser is also constructed in various shapes, and is generally less bulky than the surface condenser. The steam from the exhaust pipe of engine meeting a spray of cold water, is condensed and with the condensing water drops to the bottom of the condenser and is removed by the aid of an air pump.

This form of a condenser requires a much larger air pump than the surface condenser, the air pump for the jet condenser having to perform the double duty of the air and circulating pump for the surface condenser.

The surface condenser requires a much larger quantity of condensing water than the jet condenser.

The type of condenser to select for installation in a plant depends upon a great many local circumstances, a few of which are: Space available, condition or quality of water to be used for condensation purposes; also the cost of installation.

Q. 102. (1899-1900.) What relative duty does an air-pump perform for a condenser?

What relative duty does a circulating-pump perform for a surface condenser?

Give rule, or express in formula, for finding the diameter of a single acting air-pump for a jet condenser (using a stroke of 18 inches).

Ans. 102. The relative duty of an air pump to a condenser is to remove the water of condensation and the air that enters the condenser with the steam, and through minor leaks.

For a jet condenser, in addition to the above enumerated duties, it has to remove the condensing water.

Rule.—Multiply the total number of pounds to be condensed per minute by the number of pounds of cooling water per pound of steam; reduce the pounds of cooling water used per minute to cubic feet. Also the water of condensation; add the two together and their sum equals the volume of water to be handled per minute. Divide this volume of water by the number of strokes the pump makes multiplied by the length of the stroke and the quotient equals the cross-sectional area

of the cylinder of the pump; theoretically, for making allowance for the air to be removed, multiply the volume of water by 2.75 and the product is the area of the piston required.

When the air and water are removed a partial vacuum is formed in the condenser causing the condensing water to be lifted into it by atmospheric pressure if the vertical distance is not above 20 feet.

The relative duty of a circulating pump to a surface condenser is to circulate the condensing water through the tubes of the condenser to absorb the heat in the steam.

In addition to the volume of water to be removed there is a large quantity of air; therefore the displacement in the air pump for a jet condenser must be in excess of the volume of water to be displaced.

Good authorities place this at 2.75 times the volume of water for single acting pumps.

Formula:

For the volume of single acting pumps—

$$\text{Volume} = 2.75\,\frac{Q + q}{n}$$

In which—

$Q =$ volume of condensing water.

$q =$ volume of water for condensation.

$n =$ number of strokes of pump per minute.

Q. 103. (1899-1900.) Find the diameter of a single-acting air-pump for a condenser to an engine developing 500 I. H. P. using 18 lbs. of steam per I. H. P. per hour, exhausting into a condenser (jet) at a temperature of 140° F., using 22 lbs. of water for condensing purposes per pound of steam used; the temperature of the condensing water 60° F.; air pump with a stroke of 18 inches, making 140 strokes per minute.

Ans. 103. $500 \times 18 = 9000$ lbs. of steam to be condensed per hour $= 9000 \div 60 = 150$ lbs. per minute; $150 \times 22 = 3300$ lbs. of condensing water used per minute.

3300 lbs. of water at 60° F., volume $= 52.91$ c. ft.

150 lbs. of water at 140° F., volume $= 2.44$ c. ft.

Total volume of water to be moved per minute by air pump $= 52.91 + 2.44 = 55.35$ c. ft. $55.35 \div 70$ (strokes of pump) $= .79$ c. ft. per stroke. $.79$ c. ft. $\times 1728 = 1365.12$ c. in. $=$ volume of water per stroke of pump.

$$\frac{1365.12 \times 2.75}{18} = 208.56$$ inches, the area of the cross-section of the pump cylinder.

$$\sqrt{\frac{208.56}{7854}} = 16.3$$ inches, the diameter of the cylinder.

Or, 16″ × 18″ pump at 70 strokes per minute.

Q. 104. (1899-1900.) Upon what does the amount of condensing water depend? Give the rule, or express the formula, for finding the amount of water required.

What quantity of condensing water per pound of steam is required to condense the steam exhausting into a condenser at 140° F.; the temperature of the condensing water 60° F., and the temperature of the hot-well 110° F.

Ans. 104. The amount of condensing water depends upon its temperature entering the condenser, and the amount of heat to be absorbed

from the steam; also upon the type of condenser used; the jet condenser taking less water than the surface condenser to perform the same work; the quantity depends principally upon the difference of temperature of the water and the steam.

Rule.—Subtract from the heat of the steam at the terminal pressure, the heat in the water of condensation as it leaves the condenser, and divide this remainder by the difference in the temperatures of the water before and after passing through the condenser.

Formula—

$$Q = \frac{H W}{R}$$

In which—

Q = quantity of cooling water.

H = heat units given up by the steam in condensing.

W = weight in pounds of steam condensed.

R = difference in temperature of cooling water and that of hot well.

There must be sufficient water mixed with the steam to absorb and reduce the heat of the steam at a temperature of 140° F. to 110° F., the temperature of the hot well.

The total heat of steam at 140° F. above 32° F. = 1124.64 B. T. U.

The total heat of water from the condenser at 110° F. above 32° F. equals 78.11 B. T. U.

1124.64 — 78.11 = 1046.53 B. T. U. absorbed by the cooling water.

The difference in temperature of the cooling water and the discharge from the condenser equals 110° — 60° = 50° F.

Then 1046.53 ÷ 50 = 20.93 lbs. water to condense one pound of steam at a temperature of 140° F. to 110° F.

Electricity, Dynamos, Motors, Wiring, Etc.

Q. 60. (1896-7.) What is the difference between a kilowatt and an electrical horse power?

Ans. 60. One electrical horse-power equals 746 watts; one kilowatt equals 1,000 watts.

Then 1 kilowatt equals 1,000 divided by 746, or 1.3405 H.P. Or, again, a kilowatt is 1,000 watts. An electrical horse-power is 746 watts; therefore the difference is 254 watts.

Q. 61. (1897-8.) (a) What is a "volt"?

(b) How do you fix its value in your mind for practical purposes?

Ans. 61. (a) The volt is the practical unit of electro-motive force, electrical pressure (head) or difference of potential. It is equal to 10^8 absolute, or C.G.S. units. An electro-motive force of one volt will produce a current of one ampere when applied to a conductor having a resistance of one ohm.

(b) Practically one cell of ordinary battery gives an electro-motive force of one volt. Latimer Clark's standard cell gives 1.436 volts under favorable conditions.

The volt is usually conceived as about the E. M. F. of a Daniels cell, or the ordinary voltaic cell. This last is somewhat inaccurate, however, as the different cells have different pressures, from between .6 and .7 in the Edison Lalande to nearly two volts in the Grove, Bunsen, Grenet, etc.

One association defines the volt as the pressure induced in a conductor [one foot in length] passing through a magnetic field at such a speed as to cut the lines of force at the rate of 100,000,000 lines per second. This is a useful conception in dealing with dynamos, but would seem more real to the writer if "a field capable of an aggregate pull of 225 lbs." could be substituted for a field of 100,000,000 lines of force.

An idea of the strength of 110 volts may be obtained by putting the end of your finger in a lamp socket having this potential.

Q. 62. (1897-8.) What is an "ohm"?

(b) What is the resistance of one hundred feet of No. 19 American gage copper wire?

Ans. 62. (a) The ohm is the practical unit of electrical resistance. It is equal to 10^9 absolute, or C.G.S. units of resistance. The legal ohm is the resistance of a column of mercury 1 sq. millimeter in section, and 106 centimeters long, at a temperature of 32° F.

We have thought that the ohm was best conceived of, as the resistance of a certain length of a certain sized wire. The writer always thinks of it as the resistance of a certain piece of german silver wire that he has strung on a board between binding-posts for the purpose of estimating the resistance (internal) of voltaic cells, etc.

An idea of the resistance of one ohm may be had from the following table, which gives the number of feet and number (B. & S.) of copper wire having a resistance of one ohm:

FEET PER OHM OF WIRE (B. & S.)

94	feet of No.	20.
150	"	18.
239	"	16.
380	"	14.
605	"	12.
961	"	10.
1529	"	8.
2432	"	6.
3867	"	4.

(b) We find in Kent's tables that 124.4 ft. of No. 19 A.W.G. copper wire has a resistance of 1 ohm. Therefore 1 foot has a resistance of .008038 ohm; 100 feet a resistance of .8038 ohm.

Q. 63. (1897-8.) What is an ampere?

(b) How do you fix its value in your mind for practical purposes?

Ans. 63. (a) The ampere is a certain quantity of electricity flowing in a certain time. It is the practical unit of current. It is one-tenth of the C.G.S. unit of current. The C.G.S. unit of current is that current which, flowing through a length of one centimeter of wire, acts with a force of one dyne upon a unit of magnetism distant one centimeter from every point of the wire.

(This C.G.S. definition is a good illustration of the un-get-at-ableness of electrical definitions. The unit quantity of magnetism, or unit pole, is an imaginary thing that does not and cannot exist. The centimeter is about .4″ and the dyne about 1/445,000 of a pound, however. Is there, then, no iconoclastic balm in Gilead that will mitigate this apparently necessary evil?—Ed. Com.)

(b) An ordinary 55-volt 16 C.P. lamp requires a current of one ampere; a 110-volt lamp, .5 ampere; the ordinary 2000 C.P. arc circuit requires 9.6 amperes, or practically one C.G.S. unit.

Q. 64. (1897-8.) What is a watt?

(b) What is its value in foot-lbs. per second, and in B.T.U. per second?

Ans. 64. (a) The watt is the practical unit of electrical power. It is equal to 10,000,000 units of power in the C.G.S. system. To measure the power carried by an electrical circuit we must measure both the volts and the amperes. The product of the volts and amperes is the watts, or electrical power: 746 watts = one horse-power.

(b) The value of a watt in foot-pounds per sec. is

$$\frac{33,000}{60 \times 746} = .7373 \text{ ft. lbs.}$$

The value of a watt in B.T.U. per sec. is $.7373 \div 778 = .0009477$ H.U. per sec.

We have thought that the watt was best thought of in reference to its value in foot-pounds and in heat units. It is said that a wire will throw off about .005122 heat units per square foot of surface and per second for each degree F., that its temperature is above that of the surrounding atmosphere. Knowing the square feet of surface of the wire, the number of watts expended in it and the value of a watt in heat units, it is easy to calculate how hot the wire will become, and how much of the power is wasted in heat.

Q. 65. (1897-8.) What is Ohm's law?

Ans. 65. Ohm's law:—

$$(1)\quad \text{Amperes} = \text{volts} \div \text{ohms} = A = \frac{V}{O}$$

$$(2)\quad \text{Volts} = \text{amperes} \times \text{ohms} = V = AO$$

$$(3)\quad \text{Ohms} = \text{volts} \div \text{amperes} = O = \frac{V}{A}$$

we will have a 1000-volt circuit, or the difference of potential is said to be 1000 volts. The potential decreases along the circuit in proportion to the resistance. We would say, for instance, the positive terminal of the dynamo has 1000 volts potential, the negative terminal has zero potential. After the current has passed ten lamps the difference of potential is 500 volts, etc.

The potential of the earth is zero, and if a connection with the earth and the circuit is made at any point the current runs to earth, or is "grounded."

Q. 66. (1897-8.) What is meant by the difference of potential of a current?

Ans. 66. The potential of the current refers to the voltage between the terminals of the circuit, generally speaking. If we take, for example, an arc light circuit supplying 20 lamps requiring 50 volts per lamp,

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Q. 67. (1897-8.) What are the advantages and disadvantages of high tension currents?

Ans. 67. The advantages of high potential currents consist in the ability to transmit electricity cheaply, as a smaller wire is required to transmit a given amount of electricity at a higher potential than at a lower one. Small wires cost less than large ones.

The disadvantages of high potential currents arise from the difficulty of insulation, requiring more expensive insulators. High potentials are also dangerous to human life.

Q. 68. (1897-8.) What is a transformer and how constructed?

Ans. 68. A transformer is an apparatus for transforming currents of high potential and small amperage into currents of low potential and large amperage, and vice versa.

The kind commonly used for transforming alternating currents consists of a core of laminated iron plates with two sets of windings. The primary current is sent by the dynamo through the primary coil and an induced current is generated thereby in the secondary coil. The change in potential and amperage is regulated by the size of wire and number of turns in the different windings.

Q. 69. (1897-8.) Can a direct current be transformed? If so, how?

Ans. 69. A direct current can be transformed by means of a rotary transformer. This consists of a motor having two sets of windings and two commutators. The primary current is sent through one winding and the armature turns, generating a secondary current in the other windings. By properly proportioning the windings a current of the desired voltage can be obtained from the secondary. These machines are in common use in large central stations, where they are commonly termed "boosters." Stationary or static transformers are used for alternating currents.

Q. 70. (1897-8.) In a circuit there is a shunt that has 10 times as much resistance as the part of the main circuit between the terminals of the shunt, what part of the total current will go through the shunt?

Ans. 70. In dividing a circuit the current divides inversely proportional to the resistance of the circuits.

In case the shunted circuit has ten times the resistance of that part of the main circuit between the terminal of the shunt, there will be one-tenth as much current through the shunt as through the main connection between the terminals of the shunt. We may say that the current is therefore divided into eleven parts, one-eleventh going through the shunt and ten-elevenths going through the main circuit.

Where the main current flowing in the main circuit is too large to be conveniently measured, the ammeter is frequently placed in a shunt through which a certain definite portion of the current is known to be flowing.

Q. 71. (1897-8.) What is meant by the carrying capacity of a wire?

Ans. 71. By carrying capacity of a wire is meant the amount of current it will carry without heating to such an extent as to increase the resistance too much or to cause danger of burning the insulation or wood work.

Q. 72. (1897-8.) What is the allowable carrying capacity of the usual sizes of wire from No. 0000 to No. 18 B. and S. gage—according to the National Board of Underwriters?

Ans. 72. The rules of the National Board of Underwriters (1897) gave the following table of carrying capacities:

No. of wire, B. & S. gage.	Circular Mils.	Rubber-covered Wire. Amperes.	Weather-proof Wire. Amperes.
18	1624	3	5
16	2583	6	8
14	4107	12	16
12	6530	17	23
10	10382	24	32
8	16510	33	40
6	26250	46	64
5	33102	54	77
4	41743	65	92
3	52634	76	110
2	66373	90	131
1	83694	107	156
0	105593	129	185
00	133079	150	220
000	167805	177	262
0000	211600	210	312

Q. 73. (1897-8.) How much current is used by a 16 c-p lamp on an average?

Ans. 73. A 55-volt 16 C.P. lamp requires one ampere.

A 110-volt 16 C.P. lamp requires .5 ampere, on an average.

Q. 74. (1897-8.) What is meant by the "drop" in a circuit?

Ans. 74. The drop in a circuit means the number of volts lost in overcoming the resistance of the circuit. It corresponds to the drop in pressure along a steam pipe or water main; in the latter case sometimes called "loss of head."

Q. 75. (1897-8.) What is the allowable drop (a) for electric light wiring, (b) for wiring to motors for power?

Ans. 75. In electrical wiring for lights various percentages of drop are allowed, from 1% to 10%, depending on circumstances. The larger per cent is used when the distance is long, as it is then cheaper to generate the extra electricity than it is to put in large wires.

In wiring for motors various percentages of drop are used, from 1% to 30%, according to circumstances. It often happens that there is as much as 30% drop in street railway circuits at the end of long lines.

In ordinary shop practice about 3% drop is allowed for lights and 5% for motors.

Q. 76. (1897-8.) How can the size of wire to be used be determined for conveying a given number of amperes a given distance with a given drop?

Ans. 76. A wire which conveys a current of electricity must have an area of as many circular mils in its cross-section as is equal to 21 times the distance transmitted in feet, multiplied by the current in amperes and divided by the drop in volts.

The constant 21 equals the resistance, in ohms, of a wire one circular mil in diameter and 2 ft. in length. By taking the resistance of 2 ft. length in this calculation it is then necessary to take only the distance in feet one way in the calculation.

$$\text{Area in Cir. Mils} = \frac{21 \times \text{Amperes} \times \text{Dist. in ft.}}{\text{Drop in volts.}}$$

After finding the circular mils, look up the corresponding size of wire in a table. (See Ans. No. 72.)

Example:—150 amperes are carried 150 feet with 3% drop, 120 volts pressure. By the rule: $21 \times 150 \times 150 = 472{,}500$. The number of volts drop is $120 \times .03 = 3.6$; then $472{,}500 \div 3.6 = 131{,}233$ mils. Turning to answer No. 72, we find that this corresponds to 00 wire, very nearly.

Q. 77. (1897-8.) What is a dynamo? How does it generate electricity?

Ans. 77. A dynamo is a machine for converting energy, in the form of mechanical power, into energy in the form of an electric current, or vice versa, by the operation of setting conductors, usually coils of copper wire, to rotate in a magnetic field, or by varying a magnetic field in the presence of conductors. A dynamo consists of two essential parts, a field-magnet and an armature. The field-magnet must be magnetized either by the dynamo itself or some outside source. The armature consists of coils of insulated copper wire wound upon a core which is mounted on a shaft and caused to rotate between the poles of the field-magnet in such a manner that the lines of magnetic force passing through the coils of the armature are constantly increasing or decreasing. This action causes currents of electricity to be generated in the coils of the armature, which are collected from rings or a commutator by suitable brushes and sent out on the circuit through suitable conductors.

Q. 78. (1897-8.) What is meant by the magnetic circuit?

Ans. 78. The magnetic circuit is the path or space through which the magnetic lines or force travel.

Take, for example, the Edison dynamo. The field-magnets of this machine consist of five pieces, viz., the pole pieces D, E; cores B, C, and a yoke, A. (Fig. 8.) When the magnet is in action the strongest field is between the poles, D and E, but the magnetic circuit follows around through all the parts, D, B, A, C, E, and across to D. If an armature

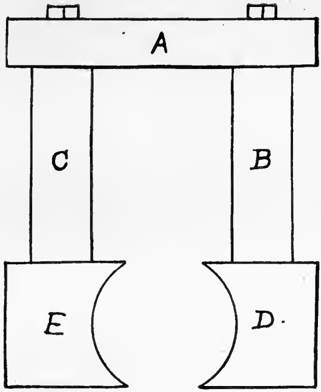


FIG. 8.

with an iron core be placed in the space between the pole-pieces, the magnetic circuit between the pole-pieces is intensified, as magnetism travels through iron easier than through air.

(Note:—In the last sentence we would say that with the same impelling force [ampere-turns] more magnetism would pass through the circuit because the resistance was less.—Ed. Com. 1897-8.)

Q. 79. (1897-8.) What is the relative permeability to magnetism of iron and air?

Ans. 79. S. P. Thompson's third edition, pages 55 and 56, says:—

"If we take the magnetic permeability of air as 1, then the permeability of iron will be represented by values lying between 5 and 20,000, according to the quality of the iron" [and the density of the lines of force].

The conception of the magnetic circuit and its close analogy to the electric circuit is comparatively modern and exceedingly useful. One can think of the air gaps as affording thousands of times as much resistance as iron of equal length and cross-section.

In Kent's handbook we find values of permeability showing that for grey cast iron it is from 37 to 800 times that of air, and that the permeability of annealed wrought iron is from 54 to 25,000 times that of air.

Q. 80. (1897-8.) Give a table of diameters for fuses for different currents.

Ans. 80. The diameter of a fuse may be calculated as follows:—

$$d = (c \div a)^{\frac{2}{3}}$$

in which d is the diameter in inches of fuse, c the number of amperes carried, and a, a constant which varies according to the material of which the fuse is composed.

The following are values of the constant, a, for the metals named: Copper = 10224; tin = 1642; lead = 1379; aluminum = 7585; iron = 3150.

From the above formula may be deduced the following:

Rule:—Divide the constant, for the given metal, by the number of amperes required; multiply this quotient by itself (square it) and

extract the cube root of this product (square). Call this result No. 1.

Second. Take unity (one) as the numerator and result No. 1 as the denominator of a fraction.

This fraction expresses in inches the diameter required.

RUPTURING CURRENT OF FUSES.

Current in Amperes	Tin Wire Diameter Inches	Tin Wire Approx. B.W.G.	Lead Wire Diameter Inches	Lead Wire Approx. B.W.G.	Copper Wire Diameter Inches	Copper Wire Approx. B.W.G.	Iron Wire Diameter Inches	Iron Wire Approx. B.W.G.	Aluminum Wire, Diam. In.
1	.0072	36	.0081	35	.0021	47	.0047	40	.0026
2	.0113	31	.0128	30	.0034	43	.0074	36	.0041
3	.0149	28	.0168	27	.0044	41	.0097	33	.0054
4	.0181	26	.0203	25	.0053	39	.0117	31	.0065
5	.0210	25	.0236	23	.0062	38	.0136	29	.0076
10	.0334	21	.0375	20	.0098	33	.0216	24	.0120
15	.0437	19	.0491	18	.0129	30	.0283	22	.0158
20	.0529	17	.0595	17	.0156	28	.0343	20.5	.0191
25	.0614	16	.0690	15	.0181	26	.0398	19	.0222
30	.0694	15	.0779	14	.0205	25	.0450	18.5	.0250
35	.0769	14.5	.0864	13.5	.0227	24	.0498	18	.0277
40	.0840	13.5	.0944	13	.0248	23	.0545	17	.0308
45	.0909	13	.1021	12	.0268	22	.0598	16.5	.0328
50	.0975	12.5	.1095	11.5	.0288	22	.0632	16	.0352
60	.1101	11	.1237	10.5	.0325	21	.0714	15	.0397
70	.1220	10	.1371	10	.0360	20	.0791	14	.0440
80	.1334	9.5	.1499	9.5	.0394	19	.0864	13.5	.0481
90	.1443	9	.1621	8	.0426	18.5	.0935	13	.0520
100	.1548	8.5	.1739	7	.0457	18	.1003	12	.0558
120	.1748	7	.1964	6	.0516	17.5	.1133	11	.0630
140	.1937	6	.2176	5	.0572	17	.1255	10	.0698
160	.2118	5	.2379	4	.0625	16	.1372	9.5	.0763
180	.2291	4	.2573	3	.0676	16	.1484	9	.0826
200	.2457	3.5	.2760	2	.0725	15	.1592	8	.0886
250	.2851	1.5	.3203	0	.0841	13.5	.1848	6.5	.1028
300	.3220	0	.3617	0.5	.0950	12.5	.2086	5	.1161
	Con. 1642.		Con. 1379.		Con. 10244.		Con. 3150.		Con. 7585

Omaha No. 1, Nebraska.

Table from Kent's M. E. Handbook, 2d Ed. Per J. A. Bramhall, Inst.

(Ex. Q. What is the diameter required for a lead fuse to carry thirty (30) amperes of current?

The constant for lead is 1379; this divided by 30 is a little less than 46; 46 multiplied by itself (square) is 2116; the cube root of 2116 is a little greater than 12.8.

Therefore the fraction is:

$$\frac{1}{12.8} = .078$$

which is the diameter required, approximately.

If one wishes to obtain the constant for a given metal or alloy, he may do so by the following formula:

$$a = \frac{c}{\sqrt{d^3}}$$

Example: A tin wire .021″ diam. melts with a current of 5 amperes, what is the constant for tin?

$$c = 5$$

$$d = .021 \therefore d^3 = .000009261$$

$$\sqrt{d^3} = \sqrt{.000009261} = .003044.$$

$$\text{Therefore constant} = a = \frac{c}{\sqrt{d^3}} = \frac{5}{.003044} = \frac{5000000}{3044} = 1642.$$

In reference to Q. 80 some of the associations have thought that no useful table could be constructed because the material of the wire varied and the result was influenced by the length of the fuse. It seems to us that the only care in reference to the length of the fuse should be, that the fuse should not be so short that its points of attachment will have an appreciable effect in conducting away and radiating the heat generated in the fuse. We think the table and formula given should prove useful.

Q. 30. (1898-9.) Give the principal Electrical Units which the engineer should be conversant with.

Ans. 30. The principal electrical units which the engineer should be familiar with are as follows:

The "Ohm"—unit of resistance; the resistance of conductor passing one "ampere" of current, when the electro-motive or impelling force is one "volt."

The "Ampere"—unit of current strength; the quantity of current flowing through the one "ohm" or resistance, when the electro-motive force is one "volt."

The Volt—unit of electro-motive force; the impelling force or "electrical pressure" required to cause "flow" of one "ampere" through a conductor offering one ohm resistance.

The Watt—unit of power; equivalent to 1-746 HP. The Kilowatt—1,000 watts.

*   *   *   *

PREFACE TO QUESTIONS 63 ET SEQ. (1 98-9).

It is a rule, rather than the exception, wheresoever steam engines and electrical generators are jointly placed in any plant, that the care and supervision of both is assigned to one "head." Such installations having become so common, the stationary engineer can no longer afford to be deficient in knowledge of the practical points involved in a matter which is universally regarded as a prime necessity, and which, by common consent, seems to have become incorporated with his other multifarious duties.

With the steam engine as the prime mover, the dynamo, with all usually appurtenant thereto, as the means for transposing the power developed, we have a combination which is quite likely to remain substantially and inseparably linked together; hence under the general condition of affairs, no engineer to-day can regard himself thoroughly equipped in his calling unless he has acquired a more than fairly good conception of the current practice which befits the case.

There can be no error, therefore, in including, under the head of "Practical Steam Engineering," such questions as are pertinent to electrical installations. While this subject in itself is too vast to permit of exhaustive treatment, yet it is hoped that the nature of the queries will afford timely discussion and thereby serve the purpose of association instruction. It will be noted that some very leading questions are asked and satisfactory answers cannot fail to interest those who are just "breaking in" on electrical matters, or who are likely to be confronted with similar propositions.

The units pertaining to electricity are of primary importance, and while these are not specifically embraced amongst the questions, it is suggested that their definitions be reviewed during association discussion, in order that the uninformed may be started with a proper understanding of their nature, their values and their application.

Q. 63. (1898-9.) What voltage do you consider best adapted for a factory plant, where motors, incandescent and arc lamps are served from one dynamo, the aggregate work approximating 100 HP? Give reasons.

Ans. 63. For a factory plant where motors, incandescent and arc lamps are served from one dynamo, a voltage of 110 would be the best. However, if lamp manufacturers would perfect a reliable 220 volt lamp this voltage for such work would have its advantages.

The advantage of 110 volts for an installation of this kind are safety and simplicity.

The disadvantages are higher expenses of copper for the power developed.

Q. 64. (1898-9.) Which is preferable for the conditions noted in Q. 63, a shunt or compound wound dynamo? How do these differ from "series" machines?

Ans. 64. A compound wound dynamo is the only satisfactory type for the work referred to in the preceding question.

In a "series" machine the current generated in the armature passes in equal strength through the field magnets and external circuit.

A "shunt" wound dynamo differs from the "series" machine in that only a comparative small part of the current generated by the armature is used for the excitation of the field coils, the greater part of the current being led direct to the external circuit. By putting more or less resistance in the "fields" of these machines, the electro-motive force at the terminals thereof may be varied.

A compound wound dynamo combines in its fields the winding of both the series and shunt machines. They may be wound to keep a constant electro-motive force at varying loads or may be "over-compounded" so as to allow for loss in feeders. This is the modern generator used for direct current incandescent lighting and for street railway work.

Q. 65. (1898-9.) A 25 HP motor is installed to drive an isolated portion of a factory; 30 arc lamps at 5 amperes each, and 300 16-c.p. incandescent lamps are required for lighting. What should be the capacity of the dynamo, in kilowatts, to furnish readily the current required for all?

Ans. 65. One horse-power is equivalent to 746 watts, the latter unit being the one used to express work done by electrical power. The kilowatt is a multiple of this unit, its value being 1,000 watts.

For the case in hand the power required for a 25 HP motor is $25 \times 746 = 18,650$ watts.

Thirty arc lamps at 5 amperes each $= 150$ amperes.

Watts $=$ amperes $\times$ volts; or $150 \times 115 = 17,250$ watts.

One 16-candle power incandescent lamp $= 56$ watts, hence for 300 lamps we have $300 \times 56 = 16,800$ watts.

Summary:

25 HP motor	= 18,650 watts.
30 arc lamps	= 17,250 watts.
300 incandescent	= 16,800 watts.
	52,700
	or 52.7 kilowatts.

Losses from various causes may be estimated at 15%, therefore a 60 K. W. generator is required for the work indicated in the question.

Q. 66. (1898-9.) Give the electrical horse-power equivalent to the work noted in Q. 65 and state the engine horse-power you would provide to drive same satisfactorily.

Ans. 66. The horse-power equivalent to work referred to in the preceding question is

$$\frac{60,000 \text{ watts}}{746} = 80 \text{ HP.}$$

An engine developing 100 actual horse-power will give satisfactory results.

Q. 73. (1898-9.) Explain the difference and advantages of bi-polar and multi-polar arc dynamos.

Ans. 73. We know of no build of multipolar "arc" machines. All arc machines so far constructed that we know anything about are bi-polar or their equivalent. (The word "arc" in the question is a palpable error.—Ed. Com.)

Incandescent machines are mostly multi-polar and are now made that way in the larger sizes; their advantages are simplicity in construction of frame and field winding, facility of access in case of needed repairs and slower speed of armature revolution.

Q. 74. (1898-9.) Name the proper material and the style of brushes best adapted for bi-polar and multi-polar machines; also give various causes for "sparking."

Ans. 74. Bi-polar machines were first fitted with copper brushes and most old machines of that type are unsuitable for carbon brushes on account of their smaller commutator surface and consequent small area allotted to a brush of this kind, causing much heating and dissatisfaction.

All multi-polar generators have liberal commutators and large brush area, hence carbon brushes are used and invariably with much satisfaction.

Causes for "sparking" are varied and many; it may be due to the following among other causes:

(a) Brushes may not be set at point of commutation.
(b) Brushes may be wedged in holders.
(c) Brushes may not be properly fitted to commutator.
(d) Brushes may not bear with sufficient pressure.
(e) Brushes may be burned on ends.
(f) Commutator may be rough.
(g) Commutator may have a loose or projecting bar.
(h) Commutator may be dirty, oily or worn.
(i) Machine may be badly designed or overloaded.
(j) Loose connection of coil to commutator, or open circuit.

Q. 75. (1898-9.) State in a general way how a dynamo should be connected to switch-board, how circuits should be run from same, and where circuit-breakers and fuses should be placed, explaining why the latter are put in.

Ans. 75. The exact arrangement of the switch-board varies with the judgment of the designer or the requirements of the case. Dynamos are generally connected from the terminal board to the switch-board by cables. Generally the positive lead is connected to one leg of the switch. The circuit switches are connected to the main switch by means of bus-bars which take the entire current from the main switch and distribute it to the different circuit switches.

Fuses and circuit breakers are used to protect the lines and machines from burning out, due to excessive current caused by short circuits or an overload, either momentary or sustained. They are generally placed betwen the machine and main switch; fuses are placed on all distributing circuits between the line and the switch.

Q. 76. (1898-9.) What is an automatic circuit-breaker? Upon what does its action depend, and what advantages has it over a fuse?

Ans. 76. An automatic circuit breaker is an apparatus for opening the circuit when an excessive amount of current passes through it. A common form depends for its action upon the principle that a bar of

iron will tend to balance itself in a solenoid. In this case the solenoid is composed of three or four turns of the entire current conductor; as the current increases, the soft iron bar raises until it trips the spring actuated switch. Their advantage over a fuse is, that in case of a momentary overload they can be quickly thrown in again, whereas a fuse takes time to replace and, under certain conditions, is a dangerous operation.

Q. 77. (1898-9.) What style "winding" is best adapted for a motor which is to run at a constant speed and carry a variable load?

Ans. 77. The shunt winding is almost universally used for motors with variable load and using direct current. This type of motor gives a very nearly constant speed with a variable load, providing the electromotive force is kept constant.

Q. 78. (1898-9.) Should motors be run on independent circuits? Why?

Ans. 78. Motors should be run on independent circuits, very often, however, they are cut in almost anywhere. The work of a motor with a variable load requires more or less current and if not on a separate circuit, unless the conductors are excessively large, will make the lights unsteady.

Q. 79. (1898-9.) What is a starting-box, and why required in connection with a motor? Explain also the automatic cut-out and the reasons for attaching same.

Ans. 79. A starting box is necessary in order to insert a resistance in the circuit, to allow the motor to build up its counter E. M. F., otherwise one or more coils would burn out, as the total current would pass through them before the armature had a chance to start revolving.

An automatic cut-out is so arranged that should the external circuit be broken, the box will automatically cut in its resistance and then open the armature circuit.

Q. 80. (1898-9.) Name the instruments generally used in connection with an electrical plant and explain what their readings indicate.

Ans. 80. Ammeter, or ampere meter, indicates the amount of current or amperage. The volt-meter indicates the electrical pressure on the line, or the voltage. The ground detector, or pilot lamps, indicate any short circuits on the line.

A watt-meter should be in every station where it is desirable to accurately determine the "out-put" of the plant.

Q. 81. (1898-9.) What general rules should be observed in making electrical connections?

Ans. 81. The metallic surfaces should be perfectly clean and make good contact. They should also be mechanically strong enough to withstand any strain likely to be encountered.

Q. 82. (1898-9.) What broad rule should be observed on the score of personal safety when handling electrical conductors?

Ans. 82. Be careful not to interpose any portion of the body where such will become a conductor of current.

A good rule for personal safety when working around electrical machines is to wear rubber gloves; use one hand only, as much as possible, and always stand on a dry or insulated spot.

Q. 1. (1899-1900.) Define electricity. From what is the term derived? State its nature as demonstrated by recent research, and upon what is electrical science founded?

Ans. 1. Electricity is the name given to the cause of all electrical phenomena, derived from the Greek word "electron," meaning amber. In the German this substance is called "bernstein," translated "burnstone." A fossil indurated vegetable juice, transparent or translucent, sometimes colorless, but usually some shade of yellow and brown; negatively electrified by friction when rubbed with fur or flannel. Amber being susceptible to a high degree of polish, it probably was in this way that its peculiar properties of attraction and repulsion was first noticed by the Greeks, which we now understand to be due to electricity. It is found in alluvial soils, beds of lignite and on sea coasts, especially the Prussian coast of the Baltic Sea.

Although electrical science has advanced sufficiently far to recognize the fact that the exact nature of electricity is unknown, recent research tends to demonstrate that all electrical phenomena are due to a peculiar strain or stress of a medium called ether; that when in this condition the ether possesses potential energy or capacity for doing work as is manifested by attractions and repulsions, by chemical decomposition, and by luminous, heating and various effects. In all probability, electricity is not a form of matter, for it possesses only two physical properties in common with material substance, namely "indestructibility and elasticity;" it possesses neither weight, extension nor any of the other physical properties of matter.

Q. 2. (1899-1900.) What are the two most essential features in acquiring a knowledge of electrical science?

Ans. 2. In acquiring a knowledge of the electrical science, the two most essential features are, first, to learn how to develop electrical action, and, second, to determine the effects produced by it.

Q. 3. (1899-1900.) The number of processes for developing electrical action is almost innumerable, but can be classified under four heads. Name them.

Ans. 3. (1) By the contact of dissimilar substances.

(2) By chemical action.

(3) By the application of heat.

(4) By magnetic induction.

Q. 4. (1899-1900.) Name five different principal ways in which the presence of electricity can be detected.

Ans. 4. (1) Cause attractions and repulsions of light particles of matter, such as feathers, pith, gold leaf, pieces of paper, etc.

(2) Decompose certain forms of matter into their various elements and cause other chemical changes.

(3) Produce motion in a freely suspended magnetic needle, such as the needle of a compass.

(4) Violently agitate the nervous systems of all animals.

(5) Heat the substance through which it acts.

Q. 5. (1899-1900.) When electricity appears to reside upon the surface of bodies under high tension, what branch of the science treats of this condition, and what are the charges termed? When they flow through the substance of a body under a comparatively low tension, what branch of the science treats of this condition?

Ans. 5. When electricity appears to reside upon the surface under a high tension, this branch of the science is termed "electro-statics," and the charges are said to be static charges of electricity. When the current appears to flow through their substance under comparatively low pressure or tension, this branch of the science is termed "electro-dynamics," and treats of the action of electric currents.

Q. 6. (1899-1900.) Describe and give some examples of static charges. What do you understand by the term positive (+) and negative (—) charges? Can a positive or negative charge be produced independent of one another? Why? What about the intensity of the charge?

Ans. 6. If a glass rod or a piece of amber is rubbed with fur or silk the parts rubbed have the property of attracting light particles of matter. These attractions and repulsions are due to a static charge residing upon the surface of these bodies, and a body in this condition is said to be electrified.

An apparatus known as an electric pendulum is often used to demonstrate a number of interesting experiments, consisting of a pith ball suspended by a silk string and a glass rod or a stick of sealing-wax, electrified by different substances, exemplifying the attractions and repulsions, according to a positive and negative electrifying of the substance.

An electric charge developed upon glass by rubbing with silk has been termed a positive (+) charge; and that developed on resinous bodies rubbed with fur or flannel, a negative (—) charge.

Neither a positive nor negative charge can be produced independent of one another, for there is always an equal quantity of both charges produced, one charge appearing on the surface of the body rubbed and an equal amount of the opposite charge upon the rubber. The intensity of the charge developed is independent of the actual amount of friction which takes place between the two bodies.

To obtain the nighest possible degree of electrification it is only necessary to bring every portion of one surface into contact with every particle or portion of the other; when this is done no extra amount of rubbing can develop any greater charge upon either surface.

Q. 7. (1899-1900.) From experiments with static charges give two laws governing the phenomena.

Ans. 7. (1) When two dissimilar substances are brought into contact, one of them always assumes the positive and the other the negative condition, although the amount may sometimes be so small as to render its detection difficult.

(2) Electrified bodies with similar charges are mutually repellant, while electrified bodies with dissimilar charges are mutually attractive.

Q. 8. (1899-1900.) Name a few of the list known as the electric series, and the relation they bear to each other.

Ans. 8. The following is the list of the electric series, and the substances so arranged that each receives a positive charge when rubbed or placed in contact with any of the bodies following it. And a negative charge when rubbed with any that precede it:

1, fur; 2, flannel; 3, ivory; 4, crystals; 5, glass; 6, cotton; 7, silk; 8, the body; 9, wood; 10, metals; 11, sealing-wax; 12, resin; 13, sulphur; 14, gutta percha; 15, gun cotton.

For example, glass when rubbed with flannel receives a negative charge, and when rubbed with sealing-wax a positive charge.

Q. 9. (1899-1900.) Explain the terms conductors, non-conductors or insulators. Give a list of good conductors; also of non-conductors.

Ans. 9. Experiments show that when a metal receives a charge at any point, the electricity immediately passes or flows through its substance to all parts. Metals, therefore, are said to be good conductors of electricity.

Experiments have also shown that in the case of the dry glass rod, or with a piece of sealing-wax or resin, that only that part of the substance which has been rubbed will be electrified, the other parts will

produce neither attractions nor repulsions. These bodies do not readily conduct electricity; that is, they oppose or resist the passage of electricity through them and are termed non-conductors of electricity.

This distinction is not absolute, for all bodies to some extent conduct electricity, while there is no known substance but what offers some resistance to the flow of the electric current.

The names of some of the most important in the list of good conductors and non-conductors are given, classified as to their conductivity, etc.:

Conductors—Silver, copper, aluminum, other metals, charcoal, water, the body.

Non-conductors—Paper, oils, porcelain, wood, silk, resins, gutta percha, shellac, ebonite, paraffine, glass, dry air, etc.

Q. 10. (1899-1900.) Define the word potential. For what is it substituted and to what is it analogous?

Ans. 10. Potential is a word substituted for the general and vague phrase, electrical condition. It is analogous with pressure in gases; heads in liquids, and temperature in heat.

Q. 11. (1899-1900.) Explain the conditions when an electrified body is connected to earth—direction of flow as regards a high or low potential in relation to earth.

Ans. 11. If an electrified body, positively charged, is connected to the earth by a conductor, electricity is said to flow from the body to the earth; but if negatively charged and connected to the earth in a similar manner, electricity is said to flow from the earth to that body. This is called the direction of flow of an electric current.

That which determines the direction of the flow is the relative electrical potential, or the pressure of the two charges in regard to the earth.

It is impossible to say with certainty in which direction electricity really flows, or, in other words, to declare which of two points has the higher or lower electrical potential, or pressure.

All that can be said with certainty is that when there is a difference of electrical potential, or pressure, electricity tends to flow from the higher to that of the lower potential or pressure.

For convenience it has been arbitrarily assumed and conventionally adopted that the positive electrical condition is at a higher potential, or pressure, than that called the negative, and that electricity tends to flow from a positively to a negatively electrified body.

Q. 12. (1899-1900.) What is meant by zero potential?

Ans. 12. The normal level of the water is taken as that of the surface of the sea, the normal pressure of air and gases, as that of the atmosphere at the sea level; similarly there is a zero potential, or pressure, of electricity in the earth itself.

The earth may be regarded as a reservoir of electricity of infinite quantity, and its potential, or pressure, taken as zero.

A positive electrical condition may be assumed to be at a higher potential, or pressure, than the earth, and that called negative is assumed to be at a lower potential than the earth.

Q. 13. (1899-1900.) What is first necessary to do in order to produce an electric current? What is the effect of placing a piece of copper and zinc together; when separated slightly and one end of each submerged in saline or acidulated water? Describe the simple voltaic or galvanic cell.

Ans. 13. To produce an electric current, it is first necessary to cause a difference of electrical potential between two bodies, or between two parts of the same body.

When two dissimilar substances are placed in contact, one always assumes the positive and the other the negative condition.

There is instantly developed a difference of potential between the two bodies.

A piece of copper and zinc placed in contact will develop a difference of electrical potential easily detected.

Should the plates be slightly separated, and one end of each submerged in a vessel containing saline or acidulated water, the same results will follow. The exposed ends of the zinc and copper are now electrified to different degrees; that is, there is a difference of potential between them.

The voltaic cell is an apparatus for developing a continuous current of electricity and consists essentially of a vessel containing saline or acidulated water, into which are submerged two plates of dissimilar metals, or one metal and a metalloid.

The exposed ends are connected by any conducting material, the potential between the plates tends to equalize and a momentary discharge passes between the exposed ends through the conductor and also between the submerged ends through the liquid.

During the passage of the current through the liquid, it causes certain chemical changes to take place; these changes in their turn show a fresh difference of potential between the plates, followed instantly by another equalizing discharge.

These changes follow one another so rapidly that they form an almost continuous current.

An electric current becomes continuous when the difference of the potential is constantly maintained.

The name given to the liquid in which the metals are submerged is "electrolyte," which, as it transmits the current, is decomposed by it.

Of the submerged ends, the zinc assumes the positive condition and the copper the negative; of the exposed ends the copper is the positive and the zinc the negative; hence the flow of the current is from the submerged end of the zinc through the electrolyte to the submerged end of the copper, thence from the exposed end of the copper through a conductor forming any outside circuit to the exposed end of the zinc, flowing continuously when the circuit is closed, or remaining passive when the circuit is open.

Q. 14. (1899-1900.) In any voltaic couple which is the positive and which is the negative element?

Ans. 14. Two dissimilar metals, when spoken of separately, are called voltaic or galvanic elements; when taken collectively, are known as a voltaic couple. The metal terminals or poles of a cell, to which the conductors are attached, are termed electrodes, the polarity of which are directly opposite to the polarity of the submerged ends of the metal substance.

The element which is acted upon by the electrolyte will always be the positive element, and its electrode or terminal the negative electrode of the cell in any voltaic couple.

Q. 15. (1899-1900.) Electromotive series; name them in the regular order and tell how the positive or negative element may be determined. Give the difference of potential in relation of one element to another of the series.

Ans. 15. The following list of voltaic elements composes what is known as the electromotive series; any two of which form a voltaic couple when submerged in an electrolyte, the one standing first on the list being the positive element to the one following it. And the difference of potential will be the greater in proportion to the distance between the two substances in the list.

For example, the difference of potential developed between zinc and

platinum is greater than between zinc and nickel, or equal to the sum of the difference of potential between zinc and nickel and between nickel and platinum.

The electromotive series:

1, zinc; 2, cadmium; 3, tin; 4, lead; 5, iron; 6, nickel; 7, bismuth; 8, antimony; 9, copper; 10, silver; 11, gold; 12, platinum; 13, graphite.

Q. 16. (1899-1900.) Name three ways in which electricity flowing as a current differs from static charges.

Ans. 16. 1. The potential is much lower. 2. Its actual quantity is much greater. 3. It is continuous.

The potential of a current of electricity is comparatively so small that a voltaic battery composed of a large number of cells is not sufficient to produce a spark of more than two-hundredths of an inch in air; whereas, a rapidly moving leather belt will sometimes produce sparks of one to three inches.

If, however, the actual quantity of electricity is measured by its effect in decomposing water, then the quantity produced by a small voltaic cell would give greater results than that from a large rapidly moving belt producing static charges several inches in length.

Q. 17. (1899-1900.) Can an electric current be developed between two non-conducting substances as in the case of static charges? Will it flow if the conductor is not made entirely of conducting material?

Ans. 17. An electric current cannot be developed between two non-conducting substances, as in the case of static charges, and it will never flow unless the conducting path is made entirely of conducting material.

Q. 18. (1899-1900.) How many ways are there of grouping the cells of a voltaic battery? Describe each, and the effect upon the potential for each grouping.

Ans. 18. There are three different ways or methods of connecting or grouping the cells of a voltaic battery: In series; in parallel or multiple-arc; in multiple series.

Cells are connected in series when the positive electrode of the first cell is connected to the negative electrode of the second, and the positive electrode of the second is connected to the negative electrode of the third cell, and so on, as shown in the diagram Fig. 1.

This method is used when there is available a large number of low potential cells and a high potential is desired, usually used for bell service and long telegraph lines or other high resistance circuits.

The potential is increased on each addition of cell, that is, if the

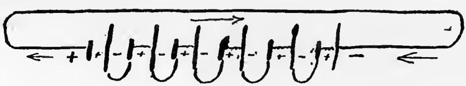


Fig. 1.

voltage of each cell is 2 volts; then a grouping of 12 cells in this manner would develop 24 volts, other groupings in the same ratio.

Should we wish to produce a strong current at a low voltage or potential, that is, when the external resistance is low, as in electroplating, the cells may be connected in parallel or multiple-arc; in this method only a part of the total current flowing in the main conductors will pass through each cell.

The diagram Fig. 2 will show the method of connection:

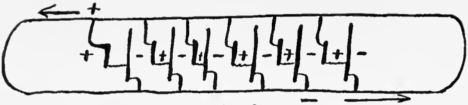


Fig. 2.

In a grouping of this kind, the potential would be equal to the potential of a single cell, no matter how many cells there are in the grouping.

Should a stronger current and a higher potential be needed, then the grouping can be in what is termed multiple-series, each group being composed of two or more cells as the case may be, connected in series and then connecting all the groups in parallel or multiple-arc.

The diagram will readily show the grouping and the effect on the potential, etc., each grouping according to the number of cells in the grouping determining the potential of the current developed, in this case the voltage equals that of two cells or four volts.

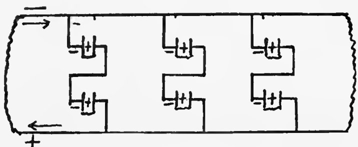


Fig. 3.

Q. 19. (1899-1900.) Describe a circuit—broken or open, closed, grounded, external and internal.

Ans. 19. A circuit is a path or a conductor, or several conductors joined together, through which an electric current flows from a given point around the conducting path back again to its starting point.

A circuit is said to be open, or broken, when its conducting elements are discontinued in such a manner as to prevent the current from flowing.

A circuit is closed or completed when its conducting elements are uninterrupted or continuous.

A circuit is said to be grounded when the earth forms a part of its conducting path.

An external circuit is that part of a circuit which is outside or external to its electric source.

An internal circuit is that part of the circuit which is included within the electric source.

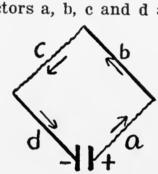
In a voltaic cell the internal circuit consists of the two metallic plates, or elements, and the electrolyte.

The external circuit, a conductor connecting the free ends of the electrodes.

Q. 20. (1899-1900.) When are conductors said to be in series? What do you understand by a shunt or derived circuit, in parallel or multiple arc? With your explanation, furnish sketch.

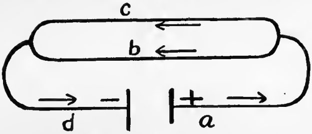
Ans. 20. Conductors are said to be a series when they are so joined together as to allow the current to pass consecutively through each.

In the diagram conductors a, b, c and d are in series.



A shunt or derived circuit is one which is divided into two or more branches, each transmitting a part of the main current.

The separate branches are said to be in parallel, or multiple-arc:



The main current flowing through the conductor (a), dividing and passing through the branches (b and c), uniting and completing the circuit through the conductor (d).

The two branches (c and b) are said to be in parallel or multiple-arc.

Q. 21. (1899-1900.) What are magnets, and to what is the term magnetism applied? Does magnetism exist in a natural state, and by what name is it known in chemistry? Where and by whom was the ore first found? From what fact was the name lodestone given to the ore? What are artificial magnets? What magnets are called permanent magnets? Describe the common form of artificial or permanent magnets? Why is a keeper used?

Ans. 21. Magnets are substances which have the property of attracting pieces of iron or steel, and the term magnetism is applied to the cause of this attraction.

Magnetism exists in a natural state in an ore of iron, which is known in chemistry as magnetic oxide of iron, or magnetite. This magnetic ore was first found by the ancients in Magnesia, a city in Asia Minor; hence substances possessing this property have been called magnets.

It was also discovered that when a small bar of the ore is suspended in a horizontal position by a thread it has the property of pointing in a north and south direction.

From this fact the name lodestone—leading-stone-was given to the ore.

When a bar or needle of hardened steel is rubbed with a piece of lodestone, it acquires magnetic properties similar to those of the lodestone, without the latter losing any of its own force. Such bars are called artificial magnets.

Artificial magnets which retain their magnetism for a long time are called permanent magnets.

The common form of artificial or permanent magnets is a bar of steel bent in the shape of a horseshoe and then hardened and magnetized.

A piece of soft iron called an armature, or a keeper, is placed across the two free ends, which helps prevent the steel from losing its magnetism.

Q. 22. (1899-1900.) What is the result of dipping a magnet into iron filings? Explain the neutral line, the poles and the axis of magnetism? Explain the polarity of a magnet, the attraction and repulsions in general.

Ans. 22. If a bar magnet is dipped into iron filings, the filings are attracted towards the two ends, and adhere to these in tufts; while towards the center of the bar, half way between the two ends, there is no such tendency.

That part of the magnet where there is no apparent attraction is called the neutral line; and the parts around the two ends, where the attraction is the greatest, are called poles. An imaginary line drawn through the center of the magnet, from end to end, connecting the two poles together, is the axis of magnetism.

Using a compass, which consists of a magnetized steel needle, resting upon a fine point, so as to turn freely in a horizontal plane, the needle, when not in the vicinity of other magnets, or magnetized iron, will always come to rest with one end pointing to the north and the other end towards the south. The end pointing northward is the north pole, and the opposite end is the south pole. This polarity applies as well to all magnets.

The attractions and repulsions are governed by the same rule as given in answer to one of the first questions. Electrified bodies with similar charges are mutually repellant, while those with dissimilar charges are mutually attractive; so it is with the polarity of magnets; unlike poles having attraction between them and like poles repelling one another.

Q. 23. (1899-1900.) How is the earth considered in relation to magnetism? Is it possible to produce a magnet of one pole?

Ans. 23. The earth is a great magnet whose magnetic poles coincide nearly, but not quite, with the true geographical north and south poles.

It is impossible to produce a magnet with only one pole. If a long bar magnet is cut into a number of pieces each part will still be a magnet and have a north and south pole.

Q. 24. (1899-1900.) What have you to say in relation to magnetic substance? What substances are magnetic and what are all other substances called?

Ans. 24. Substances which, although not in themselves magnets, not possessing polar and neutral lines, are, nevertheless, capable of being attracted by a magnet. In addition to iron and its alloys, the following elements are magnetic substances: nickel, cobalt, manganese, oxygen, cerium and chromium. These, however, possess magnetic properties in a very inferior degree compared with iron and its alloys.

All other known substances are called non-magnetic substances.

Q. 25. (1899-1900.) What is the space surrounding a magnet called? The direction of magnetic attractions and repulsions? How may the positions of lines of force be determined? How may their direction be determined?

Ans. 25. The space surrounding a magnet, in which any magnetic substance will be attracted or repelled, is called its magnetic field, or simply its field.

Magnetic attractions and repulsions are assumed to act in a definite direction, and along imaginary lines, called lines of magnetic force, and every magnetic field is assumed to be traversed by such lines of force—in fact, to exist by virtue of them. Their position may be determined (in any plane) by placing a sheet of paper over a magnet and sprinkling fine iron filings over the paper. In the case of a bar magnet lying on its side, the iron filings will arrange themselves in curved lines, extending from the north to the south poles. The nearer to the poles the more dense will be these lines of force, consequently more of the filings will converge around them.

The magnetic field looking toward either pole of a bar magnet would exhibit merely radial lines, and as in the case of the bar magnet, the lines of force will be more dense at the immediate poles.

Every line of force is assumed to pass out from the north pole, making a complete circuit through the surrounding medium and into the south pole, thence through the magnet to the north pole again. This is called the direction of the lines of force, and the path which they take is called the magnetic circuit.

By the use of a compass the direction of the lines of force can be traced; the north pole of the needle will always point in the direction of the line of force; the needle lying either parallel or tangent to the lines of force at that point.

Q. 26. (1899-1900.) Can lines of force intersect each other? What would be the result of two north poles, or two south poles, being brought near one another; or, in other words, two opposing magnetic fields? What are the resulting poles called?

Ans. 26. The lines of force can never intersect each other; when two opposing magnetic fields are brought together the lines of force from each will be crowded and distorted from their original direction until they coincide in direction with those opposing, and form a resultant field in which the direction of the lines of force will depend upon the relative strength of the two opposing negative fields, the resulting poles thus formed are called consequent poles. This would be the result of two north or two south poles being brought near each other.

Q. 27. (1899-1900.) What does every magnetic field possess? When a magnetic substance is brought into a magnetic field, what is the tendency of the lines of force? If the substance is free to move on an axis, but not bodily towards the magnetic pole, in what direction will it come to rest? What will the body then become? What position will the south pole assume?

Ans. 27. In every magnetic field there are certain stresses which produce a tension along the lines of force and a pressure across them; that is, they tend to shorten themselves from end to end, and repel one another as they lie side by side.

When a magnetic substance is brought into a magnetic field the lines of force in that vicinity crowd together and all tend to pass through the substance.

If the substance is free to move on an axis (but not bodily) towards the magnetic pole, it will always come to rest with its greatest extent or length in direction of the lines of force. The body will then become a magnet, its south pole being situated where the lines of force enter it, and its north pole where they pass out.

Q. 28. (1899-1900.) What is understood by magnetic induction? How is the quantity of magnetism expressed? What is meant by the term magnetic density?

Ans. 28. The production of magnetism in a magnetic substance in this manner is called magnetic induction. The production of artificial magnetism in a hardened steel needle or bar by contact with lodestone is one case of magnetic induction. The amount or quantity of magnetism is expressed by the total number of lines of force contained in the magnetic circuit.

Magnetic density is the number of lines of force passing through a unit area measured perpendicularly to their direction.

Q. 29. (1899-1900.) Explain how the direction of a current can be determined by the use of a compass? If a conductor conveying a current should be brought up through a piece of card-board and iron filings are sprinkled on the cardboard, how will the filings arrange themselves? What can every conductor conveying a current be imagined to be surrounded with? How, or in what manner, does the magnetic density increase or decrease? Has the subject of this question anything to do with the insurance rules, in regard to the separation of conductors, or in other words, the distance conductors shall be placed from each other?

Ans. 29. If a conductor be placed parallel to the magnetic axis of a compass needle, and a current passed through it in either direction, the needle will tend to place itself at right angles to the conductor, or, in general, an electric current and a magnet exert natural force upon each other.

Should the conductor be threaded up through a piece of cardboard and iron filings are sprinkled on the cardboard, they will arrange themselves in concentric circles around the conductor.

This effect will be observed throughout the entire length of the conductor, and is caused entirely by the current. In fact every conductor conveying a current of electricity can be imagined as completely surrounded by a sort of magnetic whirl, the magnetic density decreasing as the distance from the current increases.

The National Board of Fire Underwriters, in their national code for the installation of electric machinery and wiring of buildings have promulgated certain rules for the separation of conductors conveying currents of electricity. This magnetic influence, together with other reasons, have most certainly entered into the problem upon which they have made their decision in the matter. Granting that the proper insulation of the conductor is calculated to eliminate all danger from magnetic influence, contacts are often made through abrasions of the insulation of the conductor, which often happens through accident, carelessness or other means, the wire becoming detached from its fastening, swaying or pushed out of its proper position, etc.

In substantiation of this statement we add a quotation from their general suggestions: "In all electric work conductors, however well insulated, should always be treated as bare, to the end that under no conditions, existing or likely to exist, can a grounding or short circuit occur, and so that all leakage from conductor to conductor, or between conductor and ground, may be reduced to the minimum."

Q. 30. (1899-1900.) If the current is flowing away from the observer, in which direction will the lines of force encircle the conductor?

Ans. 30. If the current is flowing in a conductor away from the observer, then the direction of the lines of force will encircle the conductor from left to right, or in the same direction as the hands of a clock move.

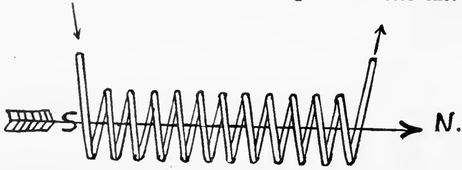
Q. 31. (1899-1900.) Explain in either case how two parallel conductors, both transmitting currents of electricity, would be, either mutually attractive or repellant? Suppose the conductor was bent into a loop, what directions would the lines of force take?

Ans. 31. Two parallel conductors, both transmitting currents of electricity, are mutually attractive or repellant, depending upon the relative direction of their currents. If the current in both conductors are flowing the same direction the lines of force will tend to surround both conductors and contract, thus attracting both conductors. If, however, the currents are flowing in opposite directions, the lines of force lying between the conductors will have the same direction and, therefore, repel the conductors.

Should the conductor be bent into a loop then all the lines of force around the conductor will thread through the loop in the same direction.

Q. 32. (1899-1900.) Describe the helix. How would the lines of force coincide with the different loops? How in relation to the helix as a whole? Furnish sketch.

Ans. 32. A helix is formed by bending a conductor into a series



of loops, or coil, the lines of force around each loop will coincide with those around the adjacent loops, forming several long lines of force which thread through the entire helix, entering at one end and passing out at the other end.

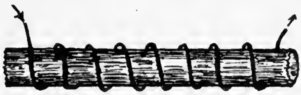
The same conditions existing in the helix as exist in the bar magnet, the lines of force pass out from one end and enter the other end, in fact having a north and south pole, a neutral line, and all the properties of attraction and repulsion of a magnet.

Q. 33. (1899-1900.) If a helix is suspended in a horizontal position, and free to turn, in what direction will it come to rest?

Ans. 33. A helix suspended in a horizontal position and free to turn, it will come to rest in a north and south direction if a current be passing through it.

Q. 34. (1899-1900.) Describe and furnish sketch of a solenoid. Upon what does the polarity of a solenoid depend?

Ans. 34. A helix made in the manner described in Answer 32 and around which a current of electricity is circulating, is called a solenoid; that is, the solenoid is the magnetizing coil of an electro magnet.



The polarity of a solenoid, that is, the direction of the lines of force which thread through it, depends upon the direction in which the conductor is coiled, and the direction of the current in the conductor.

To determine the polarity of a solenoid, knowing the direction of the current: If in looking at the end of the helix, it is so wound that the current encircles the helix in the direction of the hands of a clock, that end will be the south pole; if in the other direction it will be the north pole.

Q. 35. (1899-1900.) In looking at the end of a helix, if it is so wound that the current circulates around the helix from left to right, which end will be the north pole? If wound so that the current circulates around from right to left, which end will be the south pole? In either case, in which direction will the lines of force take through the helix?

Ans. 35. In looking at the end of a helix, so wound that the current encircles the helix from left to right, or clockwise, the end away from the observer will be the north pole. If wound so that the current encircle the helix from right to left, the end away from the observer will be the south pole. In either case the lines of force will leave the north pole and pass around and in at the south pole, through the helix to the north pole again.

Q. 36. (1899-1900.) How can the polarity of a solenoid be changed?

Ans. 36. The polarity of a solenoid can be changed by reversing the direction of the current in the conductor.

Q. 37. (1899-1900.) Why does a magnetic substance offer a better path for the lines of force than air or other non-magnetic substances? What do you understand by magnetic permeability?

Ans. 37. A magnetic substance offers a better path for the lines of force for the same reasons explained in relation to magnets in offering a better path than air or other non-magnetic substances.

The facility offered by any magnetic substance to the passage through it of the lines of force is called magnetic permeability.

The permeability of all non-magnetic substances, such as air, copper, wood, etc., is taken as 1 or unity.

The permeability of soft iron may be as high as 2,000 times that of air.

If, therefore, a piece of soft iron be inserted into the magnetic circuit of a solenoid, the number of lines of force will be greatly increased, and the iron will become highly magnetized.

Q. 38. (1899-1900.) What is an electro magnet? What is the substance around which the current circulates called? How is the solenoid generally termed?

Ans. 38. A magnet produced by inserting a magnetic substance into the magnetic circuit of a solenoid is an electro-magnet, and the substance around which the current flows or circulates is called the core. The solenoid is generally termed the magnetizing coil.

Q. 39. (1899-1900.) Describe the ordinary form of the electro-magnet; its winding, insulation and why insulation is necessary.

Ans. 39. In the ordinary form of electro-magnets the magnetizing coil consists of a large number of turns of insulated wire, that is, wire covered with a layer or coating of some non-conducting or insulating material, usually cotton or silk; otherwise the current would take a shorter and easier circuit from coil to coil througn the iron core without circulating around it; for this reason each coil is thoroughly insulated from one another that the current may be forced to make the requisite number of turns around the core for such specific purposes that the coil may be designed for.

Q. 40. (1899-1900.) How would the field coil of a motor be affected if at some point in the winding of the coil there should be a defective place in the insulation, and the current jumped through a portion of the winding instead of making the regular number of turns? Would it increase or decrease the magnetism of that particular coil? What effect would it have on the remaining coils and how would it affect the speed of the motor carrying its full rated load? How would you detect this particular trouble? What would be liable to happen if the motor should continue to run until it burned out?

Ans. 40. If, in a shunt wound, constant potential motor, one of the field-coils should be partially, or wholly, short-circuited, the magnetism in that magnet would be, according to the circumstance, below the normal, the field current would be excessive, causing the remaining coils to heat excessively, the defective coil remaining comparatively cool. The counter E. M. F. would drop, the applied E. M. F. would become excessive, and the speed of the motor would be increased to a point where the counter E. M. F. would again balance the load.

This excessive applied E. M. F. would cause the armature also to heat, and should the defect not be remedied, and the motor continue to run with a full load, the consequence would be the loss of one or all the good field coils, with, in all probability, the armature.

Q. 41. (1899-1900.) What are the three principal units used in practical measurements of a current of electricity, and what do they denote?

How would you explain them in analogy with the flow of fluids?

How would they correspond with a current flowing through a wire?

Ans. 41. The three principal units used in practical measurements of a current of electricity are:

The ampere, or the practical unit, denoting the rate of flow of an electric current, or the strength of an electric current.

The ohm, or the practical unit of resistance.

The volt, or the practical unit of electrical potential or pressure.

Explained in analogy with the flow of liquids or water, the force which causes the water to flow through the pipe is due to the head or pressure; that which resists the flow, is friction of the water against the inside of the pipe, and the amount would vary with circumstances.

The rate of flow, or the current, may be expressed in gallons per minute, and is the ratio between the head, or pressure, and the resistance of the water against the inside of the pipe. For, as head or pressure increases, the rate of flow increases in proportion; as the resistance increases the current diminishes.

In the case of an electric current flowing through a conductor, the electromotive force, or potential, corresponds to the pressure, or the head of water, and the resistance which a conductor offers to the flow of electricity to the friction of the water against the pipe.

Q. 42. (1899-1900.) The strength of a current, or the rate of flow of electricity, is a ratio. Explain this ratio?

By whom was this ratio first discovered? By whom was it first applied to electricity, and by what name has it since been called?

Ans. 42. The strength of an electric current, or the rate of flow of electricity, is also a ratio—a ratio between the electromotive force and the resistance of the conductor through which the current is flowing.

This ratio as applied to electricity was first discovered by Dr. G. S. Ohm, and has since been called "Ohm's Law."

Q. 43. (1899-1900.) What is "Ohm's law" and how is it usually expressed algebraically?

What is an ampere?

As electricity possesses neither weight nor extension, therefore, it cannot be measured like fluids or gases, how can the strength of an electric current be determined?

Ans. 43. Ohm's Law.—The strength of an electric current in any circuit is directly proportional to the electromotive force developed in that circuit and inversely proportional to the resistance of the circuit, i. e., it is equal to the electromotive force divided by the resistance.

Ohm's Law is usually expressed algebraically, thus:

$$\text{Strength of current} = \frac{\text{Electromotive force}}{\text{Resistance}}$$

If $C =$ the current in amperes.

$E =$ the electromotive force in volts.

$R =$ the resistance in ohms.

The formula will give the strength of the current (C) directly in amperes:

$$\text{Thus } C = \frac{E}{R}$$

An ampere is the unit of strength of the current.

The strength of an electric current can be described as a quantity of electricity flowing continuously every second, or, in other words, it is the rate of flow of electricity, just as the current expressed in gallons per minute is the rate of flow of liquids.

When one unit quantity of electricity is flowing continuously every second, then the rate of flow, or the strength of current, is one ampere; if two units quantities of current are flowing continuously every second then the rate of flow, or the strength of current, is two amperes, and so on.

It makes no difference in the number of amperes whether the current flows for a long time or for only a fraction of a second; if the quantity of electricity that would flow in one second is the same in both cases, then the current strength in amperes is the same.

Electricity possesses neither weight nor extension, therefore an electric current can not be measured by the usual method adopted for measuring liquids and gases.

In liquids the strength of the current is determined by measuring or weighing the actual quantity of the liquid which has passed between two points in a certain time and dividing the results by that time.

Thus, if 100 gallons of water should pass through a pipe in 5 sec., the rate of flow would be equal to $100 \div 5$, or 20 gals. per second.

The strength of an electric current, on the contrary, is determined directly by the effect it produces, and the actual quantity of electricity which has passed between two points in a certain time is afterwards calculated by multiplying the strength of the current by the time. The principal effects of an electric current were given in answer to the first set of these questions. Of these, the one most generally used for measuring, is the action of the current upon a magnetic needle.

Q. 44. (1899-1900.) Give a brief description and the use of a galvanometer.

Ans. 44. The instrument commonly used in laboratory practice is called a galvanometer.

The action of the galvanometer is based upon the principles answered in the second series of answers, where a magnetic needle suspended (freely) in the center of a looped or coiled conductor, is deflected by the current of electricity passing around the coil or loop.

In ordinary practice, the needle is suspended, either upon a point projecting into an agate cup fixed into the needle, or by a fiber suspension. In the simpler form of galvanometers, the magnetic needle itself swings over a dial graduated in degrees; in other forms, a light index needle is rigidly attached to the magnetic needle and swings over a similar dial.

In the more sensitive galvanometers a small reflecting mirror is attached to the fiber suspension and reflects a beam of light upon a horizontal scale situated several inches from the galvanometer.

In any of these galvanometers, when no current is flowing in the coils, the needle should point in a direction parallel to the length of the coil. The measuring of currents by most galvanometers depends upon the magnetic needle being held in position by the magnetic attraction of the earth's magnetism or the attraction of some adjacent magnet.

When a current of electricity passes around the coil, the tendency is to deflect the magnetic needle at right angles to its original position, while the tendency of the earth's magnetism is to oppose the movement. The couple thereby produced will cause the needle to be deflected a certain number of degrees from its original position, depending upon the relative strength of the two magnetic fields. The stronger the current in the coil the greater the deflection. With a galvanometer of standard dimensions and a magnetic field of known strength, such as the earth's magnetism at a convenient place on its surface, a strength of a current can be conveniently adopted as a unit which will produce a certain deflection; all other galvanometers can be calibrated from this standard, and their dials graduated to read the strength of currents directly in the conventional unit adopted.

Q. 45. (1899-1900.) What is the ohm?

How can electric resistance be defined?

What is one of the most important quantities in electrical measurements?

What is meant by the international ohm?

Ans. 45. The ohm is the unit of resistance.

It has been previously stated that the resistance varies in different substances; that is, one substance offers a higher resistance to a current of electricity than another. Electrical resistance can, therefore, be defined as a property of matter, varying with different substances, and in virtue of which such matter opposes or resists a passage of electricity.

The resistance which all substances offer to the passage of an electric current is one of the most important quantities in electrical measurement. In the first place, it is that which determines the strength of an electric current in any circuit in which a difference of potential is consequently maintained, as shown in Ohm's Law. In the second place, the unit of resistance, the ohm, is the only unit in electrical measurements for which a material standard can be adopted, other quantities being measured by the effect they produce.

The basis of any system of physical measurements is generally some material standard, conventionally adopted as a unit, physical measurements in each system being made in comparison with that unit.

The unit of electrical resistance now universally adopted is called the international ohm.

One international ohm is the resistance offered by a column of pure mercury 106.3 centimeters in length, 1 square millimeter in sectional area at 32° F., or at a temperature of melting ice.

The dimensions of the column expressed in inches are as follows: Length, 41.85 inches; sectional area, .00155 sq. inch.

Q. 46. (1899-1900.) What is said of the resistance of conductors at equal temperatures, irrespective of the current flowing through them, or the electro-motive force of the current?

In a given conductor, which offers a resistance of 2 ohms to a current of 1 ampere, what would be the resistance in the same conductor if 12 amperes were flowing through it?

Ans. 46. The resistance of a given conductor at equal temperatures is always constant, irrespective of the strength of current flowing through it or the electromotive force of the current.

Hence, if a given conductor offers a resistance of 2 ohms to a current of 1 ampere, it offers the same amount of resistance, no more nor less, to a current of 12 amperes.

Q. 47. (1899-1900.) How is the resistance of a given conductor influenced by a change in length?

What will be the resistance of two miles of copper wire, if the resistance of ten feet of the same wire is .013 ohms?

Ans. 47. If the length of a conductor be doubled, its resistance will be doubled; that is, the resistance of a given conductor increases as the length of the conductor increases, the resistance being directly proportional to the length of the conductor.

When it is required to find the resistance of a conductor of which the length is varied, other conditions remain unchanged, the following formula may be used:

$$r_2 = \frac{r_1 \, l_2}{l_1}$$

In which
r_1 = the original resistance;
r_2 = the required resistance;
l_1 = the original length;
l_2 = the changed length.

As in all examples of proportion, the two lengths must be reduced to the same unit.

By this formula we see that the resistance of a conductor after its length is changed is equal to the original resistance multiplied by the changed length, and the product divided by the original length.

In two miles there are 10,560 ft.

Then by our formula—

$$\text{The required resistance} = \frac{.013 \times 10560}{10} = 13.728 \text{ ohms.}$$

Q. 48. (1899-1900.) How is the resistance of a given conductor influenced by a change of the area of the conductor?

If the resistance of a conductor, whose sectional area is .025 sq. in. is .32 ohms, what will be the resistance of a conductor if its sectional area is increased to .25 sq. in.? How does the resistance of a round conductor vary?

The resistance of a round copper wire .2 inches diameter is 45 ohms; what will be the resistance of the same kind of wire .4 inches in diameter? What is said of the resistance of two or more conductors in series?

Ans. 48. If the sectional area of a conductor is doubled, the resistance will be halved. We may, then, obtain the value of the resistance of a conductor from any change of sectional area by the following formula:

$$r_2 = \frac{r_1 \, a_1}{a_2}$$

In which—
r_1 = the original resistance of the conductor;
r_2 = the changed resistance;
a_1 = the original area;
a_2 = the changed area.

From the relations here expressed it will be seen that the resistance varies inversely as the sectional area; that is, the resistance of a given conductor diminishes as its sectional area increases.

The resistance of a conductor is independent of the shape of its cross-section.

By our formula the conditions as stated—

Sectional area = .025 sq. in.
Resistance = .32 ohms. | changed area .25 sq. in.

$$\text{The required resistance} = \frac{.32 \times .025}{.25} = .032 \text{ ohms.}$$

When comparing resistance of round copper wire the following formula is used:

$$r_2 = \frac{r_1 \, D^2}{d_2}$$

In which—
r_1 = the original, or known, resistance;
r_2 = the required resistance;
D = the original diameter;
d = the changed diameter.

This formula is based on the rule that, since the sectional area of a round conductor is proportional to the square of its diameter (sectional

area = diameter squared multiplied by the constant .7854), the resistance of a round conductor is inversely proportional to the square of its diameter.

By our formula conditions as stated in the question—

A round copper wire .2 inches diameter;

The resistance 45 ohms;

The resistance when the diameter is increased to .4 inches, by our formula will be equal to the original resistance multiplied by the diameter squared, divided by the changed diameter squared.

Thus—

$$\text{Required resistance} = \frac{45 \times .2^2}{.4^2} = \frac{45 \times .4}{.16} = 11.25 \text{ ohms.}$$

The resistance of two or more conductors connected in series is equal to the sum of their separate resistances. As an example, if four conductors having separate resistances 7, 11, 13 and 19 ohms, respectively, are connected in series, their total, or joint, resistance will be equal to the sum of the separate resistances, or 50 ohms.

Q. 49. (1899-1900.) What is a microhm? For what was it devised?

In order to compare resistances of different substances how should the dimensions compare? Why?

What metal under like conditions offers the least resistance? What other metal comes next?

Does the resistance of a given conductor always remain constant? Why? Does the resistance increase or decrease as the temperature raises or lowers? How is this, in comparison with liquids and carbons?

Ans. 49. The microhm is a unit of resistance devised to facilitate calculations and measurements of exceedingly small resistances, and is equal to one-millionth of an ohm (1/1,000,000).

In order to compare the resistances of different substances, the dimensions of the pieces to be measured must be equal; for, by changing its dimensions, a good conductor may be made to offer the same resistance as an inferior one.

Under like conditions, annealed silver offers the least resistance of all known substances; soft annealed copper comes next on the list, and then follow all other metals and conductors.

The resistance of a given conductor, however, is not always constant, it changes with the temperature of the conductor.

In all metals the resistance increases as the temperature rises.

In liquids and carbons the resistance decreases as the temperature rises.

Q. 50. (1899-1900.) What is the variation of the resistance of a conductor caused by a change of temperature of 1° called?

How would you find the resistance of a conductor, after its temperature had risen, knowing its original resistance and the number of degrees rise in temperature, other conditions remaining the same?

The resistance of a piece of copper wire at 32° is 40 ohms; determine its resistance when its temperature is 74° F., the temperature coefficient for copper is .002155.

How would you determine the resistance if the temperature is dropped, other conditions remaining the same?

If the original resistance of a German silver wire is 16 ohms, determine its resistance after its temperature has fallen 15° F. Temperature coefficient of German silver is .000244.

Ans. 50. The amount of variation in the resistance caused by a change of temperature for one degree is called the temperature coefficient.

These co-efficients, however, hold true for a limited change of temperature, and should not be used with extreme changes.

To find the resistance of a conductor after its temperature has risen, knowing its original resistance and the number of degrees rise, other conditions remaining unchanged, multiply the original resistance by 1 plus the product of the number of degrees rise and the temperature co-efficient.

Formula—

$$r_2 = r_1 (1 + t k)$$

In which—

r_1 = the original resistance;
r_2 = the resistance after the temperature change;
t = rise or fall of temperature in degrees F.;
k = temperature co-efficient.

Resistance of copper wire at 32° F. is 40 ohms.

At a temperature of 74° F. (equals 42° F. rise) the temperature co-efficient is .002155.

Then, according to our rule, or formula—

The changed resistance $= 40\ (1 + 42 \times .002155) = 43.6204$ ohms.

To determine the resistance if the temperature drops: Divide the original resistance by 1 plus the product of the number of degrees fall and the temp. coef.

Formula—

$$r_2 = \frac{r^1}{1 + t k}$$

The letters having the same value as above.

If the original resistance of a German silver wire is 16 ohms; the temp. drops 15° F. the temp. coef. of German silver wire is .000244.

By our rule or formula—

$$\text{The changed resistance} = \frac{16}{1 + 15 \times .000244} = 15.941 \text{ ohms.}$$

Q. 51. (1899-1900.) What is understood by specific resistance of substances?

What instrument is usually used in measuring resistances? Give a brief description of this instrument.

Ans. 51. Specific resistance is the term given to the resistance of substances of unit length and unit sectional area at some standard temperature.

The specific resistance of a substance is the resistance of a piece of that substance one inch in length and one square inch in sectional area at 32° F.; that is, at a temp. of melting ice; this may also be expressed as the resistance of a cube of that substance taken between two opposing faces.

A list of the common metals in the order of their relative resistances beginning with silver as offering the least resistance:

Silver, annealed	1.000
Silver, hard drawn	1.086
Copper, annealed	1.063
Copper, hard drawn	1.086

Etc., etc.

An instrument known as "Wheatstone Bridge" is usually used in laboratory practice in determining the resistance of different substances, coils, etc.

These are different forms of construction, some simple, others elaborate, with a galvanometer in circuit.

A simple form in laboratory practice, where small currents are used and great accuracy is required, the resistance coils are enclosed in a

wooden box and the actual resistance of each coil is carefully determined, the separate coils offering resistances from one ohm upward to 5,000 ohms.

The operation of adjusting the resistance is by the means of removal plugs, allowing the current to pass through all or part of the coils, as the case may require.

Q. 52. (1899-1900.) What does the term "volt" denote? What three facts are to be carefully noted regarding the application of "Ohm's law" to closed circuits?

Ans. 52. The volt is the practical unit of electromotive force.

In mechanics, pressures of all kinds are measured by the effects they produce; similarly, in electrotechnics, potential is measured by the effect it produces.

By definition the volt is that electromotive force which will maintain a current of one ampere in a circuit of one ohm's resistance.

With a known resistance in ohms and a known strength of current in amperes the electromotive force is determined by "Ohm's" law, in which the current in amperes multiplied by the resistance in ohms equals the electromotive force in volts.

Or, $E = C\ R$.

$E =$ electromotive force in volts.

$C =$ current in amperes.

$R =$ resistance in ohms.

The application of Ohm's law to closed circuits, the following facts are to be carefully noted:

The current (C) is the same in all parts of the circuit, except in the cases of derived circuits, where the sum of the currents in the separate branches equal to the current in the main, or undivided, branches.

The resistance (R) is the resistance of the internal circuit plus the resistance of the external circuit.

Q. 53. (1899-1900.) How do you determine the strength of a current in amperes, the E. M. F. and R. being given?

If the two electrodes of a simple galvanic cell are connected by a conductor whose resistance is 1.5 ohms; the internal resistance of the cell is 6 ohms, and the total E. M. F. developed is 1.83 volts, what is the strength of the current flowing in the circuit?

Ans. 53. The strength of the current (C) in amperes divided by the resistance (R) in ohms equals the electromotive force (E) in volts.

Internal resistance	6. ohms.
External resistance	1.5 ohms.
Total resistance of..............	7.5 ohms.

Then, according to Ohm's law—

$$C = \frac{E}{R} = \frac{1.83}{7.5} = .244 \text{ amperes.}$$

The strength of the current flowing in the circuit.

Q. 54. (1899-1900.) How would you find the total resistance in ohms of a closed circuit when the E. M. F. and the strength of the current is known?

The total E. M. F. developed in a closed circuit, 1.7 volts, and the current is .7 amperes; find the resistance in ohms.

Ans. 54. The total resistance in ohms of a closed circuit equals the electromotive force (E) in volts divided by the strength of the current (C) in amperes.

Electromotive force $= 1.7$ volts.
Current $= .7$ amperes.

The resistance equals $\frac{1.7}{.7} = 2.428$ ohms.

The resistance in the circuit.

Q. 55. (1899-1900.) It is desired to transmit a current of 15 amperes to a receptive device, situated 1,000 feet from the source; the total E. M. F. generated is 125 volts, and only 1-10 of this potential is to be lost in the conductors, leading to and from the device; find the resistance of the two conductors. How much will be the resistance per foot of the conductors?

In a voltaic cell, what is to be understood by the term, available or external E. M. F.?

The internal or generated E. M. F.?

Ans. 55. 1/10 of 125 volts $= 12.5$ volts, which represents the drop, or loss in potential on the two conductors.

Let—
$E^1 = 12.5$ volts.
$C =$ the current in amps. 15.
$R^1 =$ total resistance of the two conductors.
Then—

$$R^1 = \frac{E^1}{C} = \frac{12.5}{15} = .8333 + \text{ohms.}$$

The resistance per foot of conductor equals—

$$\frac{.8333 +}{2000} = .0004166 + \text{ohms.}$$

The difference of potential between the two electrodes of a simple voltaic cell when no current is flowing; that is, when the circuit is open, is always equal to the total E. M. F. developed in the cell, and is called the internal, or generated, E. M. F.

When a current is flowing; that is, when the circuit is closed. a certain amount of the potential is expended in forcing the current through the internal resistance of the cell itself.

Hence, the difference of potential between the two electrodes when the circuit is closed is always smaller than when the circuit is open.

This difference of potential between the two electrodes when the circuit is closed, is called the available, or external, E. M. F., to distinguish it from the internal, or total, generated E. M. F.

Q. 56. (1899-1900.) In a voltaic cell, the total generated E. M. F. equals 2.5 volts, and the internal resistance is .7 ohms; if a current of 1.5 amps. flows through the cell when the circuit is closed, what is the available E. M. F. developed by the cell, or what is the difference in potential between the two electrodes?

How do you find the E. M. F. (in volts) in a closed circuit when the strength of the current and the total resistance is known?

Ans. 56. To find the available E. M. F. of a cell:

Let—
$E =$ the total generated E. M. F.;
$E^1 =$ the available E. M. F. when the circuit is closed;
$C =$ the current in amp. flowing when the circuit is closed;
$r_1 =$ the internal resistance of the cell.
Then the drop, or loss, of potential in the cell equals $C\,r_1$.
The available E. M. F. $E^1 = E - C\,r_1$.

If the total E. M. F. equals 2.5 volts; the internal resistance equals .7 ohms; with a current flowing of 1.5 amps., the available E. M. F. will equal—

$$E_1 = E - C\, r_1 = 2.5 - 1.5 \times .7 = 1.45 \text{ volts}$$

or the difference in potential between the two electrodes when the circuit is closed.

To find the E. M. F. (in volts) in a closed circuit, when the strength of the current and the total resistance is known:

The available E. M. F. of a cell is equal to the difference between the total generated E. M. F. and the potential expended in forcing the current through the internal resistance of the cell when the circuit is closed.

From Ohm's Law: This drop of potential in the cell itself is equal to the product of the internal resistance in ohms and the strength of the current in amps. flowing through the circuit.

Q. 57. (1899-1900.) The internal resistance of a closed circuit is 3 ohms, and the external resistance is 4 ohms, the current flowing is .5 amperes; what is the E. M. F. developed?

What is understood by a drop of potential? How is this drop usually expressed?

If a circuit in which a current of 4 amperes is flowing having three separate resistances as (in diagram) a to b, b to c ,and c to d, the resistance from a to b 1.6 ohms, b to c is 3.2 ohms and c to d 4.3 ohms, find the difference in potential from a to b, b to c and c to d? And from a to d?

Give a general explanation of conductivity in regard to resistance?

When the resistance of two branches are unequal, how will the current divide between them in a derived circuit?

Ans. 57—

Let R = total resistance $= r_1 + r_2 = .7$ ohms.

r^1 = internal resistance; 3 ohms.

r_2 = external resistance; 4 ohms.

C = current in amps. .5 amps.

The total E. M. F. $= C\,R = .5 \times 7 = 3.5$ volts.

The drop in potential $= Cr^1 = .5 \times 3 = 1.5$ volts.

The available E. M. F. $= 3.5 - 1.5 = 2.0$ volts.

Drop or loss of Potential:—

By referring again to water flowing through a pipe; though the quantity of water which passes is the same at any cross section of the pipe, the pressure per square inch is not the same. It is this difference of pressure that causes the water to flow between two points against the friction of the pipes.

This is precisely similar to a current of electricity flowing through a conductor. Though the quantity of electricity that flows is equal at all cross sections, the E. M. F. is by no means the same at all points along the conductor.

It suffers a loss or drop of electrical potential in the direction in which the current is flowing, and it is this difference of electrical potential that causes the electricity to flow against the resistance of the conductor. Ohm's law not only gives the strength of a current in a closed circuit, but also the difference of potential in volts along the circuit.

The difference of potential (E^1) in volts between any two points is equal to the product of the strength of the current (C) in amperes and

the resistance (R^1) in ohm's of that part of the circuit between those two points, or—

$$E^1 = C\,R^1$$

E^1 also represents the loss or drop of potential in volts between the two points.

If any two of these quantities are known the third can readily be found, for by transposing—

$$C = \frac{E^1}{R^1} \text{ and } R^1 = \frac{E^1}{C}.$$

See sketch— R^1 = separate resistances, E^1 = the drop in potential between a and d, according to Ohm's law.

$$E^1 = C\,R^1$$

The difference of potential between—

a and b = 4 × 1.6 = 6.4 volts.
b and c = 4 × 3.2 = 12.8 volts.
c and d = 4 × 4.3 = 17.2 volts.

a and d = 36.4 volts.

36.4 volts represents the drop of potential caused by a current of 4 amperes flowing between the points a and d.

Conductivity can be defined as the facility with which a body transmits electricity, and is the opposite to resistance.

For example, copper is high conductivity with low resistance; mercury is high resistance and low conductivity.

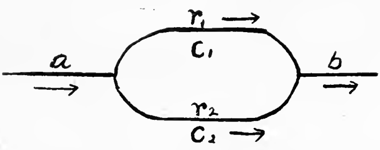
In other words, conductivity is the inverse or reciprocal of resistance.

The conductivity of any conductor is, therefore, unity divided by the resistance of that conductor; and conversely the resistance of any conductor is unity divided by its conductivity.

When the current flows through two branches of a derived circuit and the resistances are equal the current will divide equally between the two branches.

When the resistances of the two branches are unequal, the current will divide between them in inverse proportion to their respective resistances.

Q. 58. (1899-1900.) In the accompanying diagram, if the resistance $r_1 = 2$ ohms, and the resistance of $r_2 = 4$ ohms, find the separate cur-



rent, c_1 and c_2, in the two branches respectively? When C = (main current), 30 amperes, in the undivided mains, a and b.

If the separate resistances of two conductors are equal, what will be their joint resistance when connected in parallel?

Give the rule when the separate resistances are unequal?

What is the joint resistance when three or more conductors are connected in parallel?

In a derived circuit of any number of branches, what would be the difference of potential between where the branches divide and where they unite?

How can the separate resistances of the branches of a derived circuit be determined?

Ans. 58. See sketch:

$r_1 = 2$ ohms;

$r_2 = 4$ ohms;

$C = 30$ amperes;

$c_1 =$ current in one branch of the derived circuit;

$C_2 =$ current in the other branch of the derived circuit.

The resistances in the two branches are r_1 and r_2, therefore, $c_1 : c_2 :: r_2 : r_1$.

By algebra this proportion gives the two following formulas:

For the first branch $c_1 = \frac{Cr_2}{r_1 + r_2} = \frac{30 \times 4}{2 + 4} = \frac{120}{6} = 20$ amps

For the second branch $c_2 = \frac{Cr_1}{r_1 + r_2} = \frac{30 \times 2}{2 + 4} = \frac{60}{6} = 10$ amps

In the branch c_1 20 amperes of current will flow.

In the branch c_2 10 amperes of current will flow.

Reducing our formula to rule we have for the first branch.

Of two branches in parallel, dividing from a main circuit, the current in the first branch is equal to the current in the main multiplied by the resistance of the second branch, the product divided by the sum of the resistances of the two branches.

For the second branch,

The current of the second branch is equal to the current of the main circuit multiplied by the resistance of the first branch, the product divided by the sum of the resistances of the two branches.

If the resistances of two conductors are equal, their joint resistance when connected in parallel is one-half the resistance of either conductor.

When the separate resistances of two conductors in parallel are unequal, the determination of their joint resistance when connected in parellel involves some calculation.

Referring to the diagram, the conductivities of the branches are

$$\frac{1}{r_1} \text{ and } \frac{1}{r_2}, \text{ respectively.}$$

Hence their joint conductivity when connected in parallel is

$$\frac{1}{r_1} + \frac{1}{r_2} = \frac{r_2 + r_1}{r_1 \ r_2};$$

Now, since the resistance of any conductor is the reciprocal of its conductivity, then the joint resistance of the two branches in parallel is the reciprocal of their joint conductivity;

$$\text{or, } 1 \div \frac{r_2 + r^1}{r_1 \ r_2} = \frac{r_1 \ r_2}{r_2 + r_1}.$$

Hence, joint resistance $R^{11} = \frac{r_1 \ r_2}{r_1 + r_2}$.

That is, the joint resistance of two conductors connected in parallel is equal to the product of their separate resistances divided by the sum of their separate resistances.

The joint resistance of three or more conductors, connected in parallel, is equal to the reciprocal of their joint conductivity.

If in our diagram we connect in another conductor, making three instead of two branches, then the joint resistance of the three branches in parallel $R^{111} = \frac{r_1 \ r_2 \ r_3}{r_2 \ r_3 + r_1 \ r_2 + r_1 \ r_3}$

In a derived circuit of any number of branches, the difference of potential between where they divide and where they unite is equal to the product of the sum of the currents in the separate branches and their joint resistance in parallel.

The separate currents in the branches of a derived circuit can be determined by finding the difference of potential between where the branches divide and where they unite again, and dividing the result by the separate resistance of each branch.

The separate resistance of the branches of a derived circuit can be determined by finding the difference of potential between where the branches divide and where they unite, dividing the result by the separate currents of each branch.

Examples of the three conditions:

First condition—

If the currents in the three branches are 16, 8 and 4 amperes, respectively, and the joint resistance is 2 6-7 ohms, then the difference of potential between a and b

$$= (16 + 8 + 4)\ 2\frac{6}{7} = 28 \times \frac{20}{7} = 80 \text{ volts}$$

Second condition—

Assume that the separate resistances of the three branches are, respectively, 5, 10 and 20 ohms, and the difference of potential from a to b is 80 volts. Then the current in the first branch is equal to $80 \div 5 = 16$ amps; second branch to $80 \div 10 = 8$ amps; third branch to $80 \div 20 = 4$ amps.

If the difference of potential between a and b is 80 volts, and the currents in the separate branches are 16, 8 and 4 amperes, respectively, then the resistance of the first branch is $80 \div 16 = 5$ ohms; second branch is $80 \div 8 = 10$ ohms; third branch is $80 \div 4 = 20$ ohms.

Q. 59. (1899-1900.) How can the strength of an electric current be defined?

What is the practical unit of electrical quantity, and what does it represent? What is the rule for calculating the quantity of electricity which has passed in a circuit in a given time when the strength in amperes is known? Explain, briefly, the term electrical work?

The principle of the conservation of energy teaches that energy cannot be destroyed; what follows in regard to electrical energy?

How would you find the amount of electrical work accomplished, in joules, during a given time in any circuit?

Ans. 59. The strength of an electric current can be defined as a quantity of electricity flowing in one second.

The practical unit of electricity is called the coulomb.

The coulomb is such a quantity of electricity as would pass in one second through a circuit in which the strength of the current is one ampere.

To calculate the quantity of electricity which has passed in a circuit in a given time when the strength of the current in amperes is known:

Let $Q =$ the quantity in coulombs;
$C =$ the strength of current in amperes;
$t =$ the time.

Then $Q = Ct$.

If any two of these quantities are known the third can be readily found.

By transposition, $C = \frac{Q}{t}$, or $t = \frac{Q}{C}$.

Electrical Work:—

When an electric current flows from a higher to a lower potential, electrical energy is expended, and work is done by the current.

The principle of the conservation of energy teaches that energy can never be destroyed; it follows, therefore, that if energy has to be expended in forcing a quantity of electricity against a certain amount of resistance, the equivalent of that energy must be transformed into some other form. This other form is usually heat; that is, when a quantity of electricity flows against the resistance of a conductor, a certain amount of electrical energy is transformed into heat energy. The actual amount of heat developed is an exact equivalent of the work done in overcoming the resistance of the conductor, and varies directly as the resistance.

For example, take two wires, the resistance of one being twice that of the other, and send currents of equal strength through each.

The amount of heat developed in the wire of higher resistance will be twice that developed in the wire offering the lower resistance.

The unit used to express the amount of mechanical work done is known as the foot-pound.

The work done, in raising any mass through any height, is found by multiplying the weight of the body lifted by the vertical height through which it is raised; similarly, the practical unit of electrical work is that amount accomplished when a unit quantity of electricity, one coulomb, flows between a potential of one volt.

The unit of electrical work is, therefore, the volt-coulomb, and is called the joule.

1 joule = .7373 foot-pound.

By the means of the following formulas, we may find directly the amount of electrical work accomplished in joules during a given time in any circuit.

Let—

J = electrical work in joules;
C = current, in amps;
t = time, in seconds;
E = potential or E. M. F., of circuit;
R = resistance of circuit.

When the E. M. F. and current are known,

$$J = C\,E\,t.$$

When the current and resistance are known,

$$J = C^2\,R\,t.$$

When the E. M. F. and resistance are known,

$$J = \frac{E^2\,t}{R}.$$

To reduce the work as expressed in joules to foot-pounds—

$$\text{foot-pounds} = \text{Joules} \times .7373$$

Q. 60. (1899-1900.) What is the unit of power or rate of doing work called? Give three rules for computing the power in watts. Give four rules for determining the H. P. The H. P. being given, how would the number of watts be determined? Either way, how would the same be expressed in kilowatts?

Ans. 60. Power, or rate of doing work, is found by dividing the amount of work done by the time required to do it.

In mechanics, the unit of power is called the horse-power.

In electrotechnics, the unit of power is the watt.

It is found by dividing the amount of electrical work done by the time required to do it.

Let—

E = E. M. F. in volts;
Q = quantity of electricity in coulombs;
C = current in amps;
W = the power in watts.

By previous formula the amount of electrical work, $J = C\,E\,t$.

Then—

$$W = \frac{C\,E\,t}{t} = C\,E.$$

Rule: The power in watts is equal to the strength of the current in amperes multiplied by the E. M. F. in volts.

$$W = \frac{C^2\,R\,t}{t} = C^2R.$$

Rule: The power in watts is equal to the strength of the current in amperes squared multiplied by the resistance in ohms—

$$W = \frac{E^2\,t}{R\,t} = \frac{E^2}{R}.$$

Rule:

The power in watts is equal to the quotient arising from dividing the E. M. F. in volts squared by the resistance in ohms.

$$H\,P = 746 \text{ watts or } 1 \text{ watt} = \frac{1}{746}\,H\,P.$$

$$H\,P = \frac{W}{746}.$$

To express the rate of doing work (electrical) in horse-power units, divide the number of watts by 746.

$$H\,P = \frac{E\,C}{746}. \quad H\,P = \frac{C^2\,R}{746}. \quad H\,P = \frac{E^2}{746\,R}.$$

To express the electrical power in kilo-watts.

1,000 watts equal 1 kilo-watt.

By substituting 1,000 for 746 in the preceding formulas the results obtained will be in kilo-watts.

Q. 61. (1900-01.) When is an electric current generated in a conductor?

Name two experiments from which the foregoing principle is deducted.

To what are due currents generated in a conductor cutting lines of force and those induced in a coiled conductor by a change in the number of lines of force?

Give brief explanation.

In calculations how is it convenient to make distinctions between the two cases?

In these explanations what caution should be observed?

Ans. 61. An electric current is generated in a conductor when that conductor is moved across a magnetic field, so as to cut the lines of force at an angle.

If a coiled conductor be straightened out, forming one long conductor, then be moved across the magnetic field at right angles to the lines of force, a current will be generated in the circuit. The current, however, immediately subsides when the motion ceases, no matter whether the conductor is in the magnetic field or not.

Should the conductor be moved in the magnetic field with its length parallel to the lines of force, no current will be generated in the circuit.

In reality currents generated in a conductor cutting lines of force

and those induced in a coiled conductor by a change in number of lines of force which pass through the coil, are due to the same movement.

For every conductor conveying an electric current forms a closed coil and every line of force is a complete circuit by itself. Consequently, where any part of a closed coil is cutting lines of force the lines of force are passing through the coil in a definite direction and changing at the same rate as the cutting.

For example, if a closed coil is represented by a heavy loop and a light loop represents four lines of force. When the two closed loops are brought together, the closed coil is cut at one place by four lines of force and at the same time the number of lines of force passing through the closed coil increases from nothing to four.

In calculations, however, it is convenient to make distinctions between the two cases; in the one case, to consider that the current is generated by a conductor of a certain length cutting lines of force at right angles; and, in the other case, to consider that the current in a closed coil is induced by the change in the number of the lines of force passing through the coil.

In these explanations it must not be forgotten that an electric current is the result of a difference of potential or electromotive force. Consequently it is not actually a current that is generated in the moving wire, but an electromotive force; for, in all of the previous experiments in which currents are induced or generated in a conductor by the lines of force, if the circuit is opened at any point, no current will flow, but the electromotive force still exists.

Q. 62. (1900-01.) How many methods are known of producing an electromotive force by induction in a coiled conductor?

Name them.

Explain each method.

Ans. 62. There are three methods of producing an electromotive force by induction in a coiled conductor—i. e.,

"a"—Electro-magnetic induction.

"b"—Self induction.

"c"—Mutual induction.

In electro-magnetic induction the change in the number of lines of force which pass through the coil is due to some relative movement between the coil and a magnetic movement. For example, by thrusting a magnet into the coil or withdrawing it; or again, by suddenly thrusting the coil into a magnetic field with its plane at right angles to the lines of force.

In self induction the change in the number of lines of force is caused by sudden changes in a current which is already flowing through the coil itself, and is supplied from some exterior source.

This exterior current produces a magnetic field in the coil itself, and for so long as the strength of the current remained constant there is no change in the number of lines of force which pass through the coil.

Should the strength of the current be suddenly increased, a change in the number of lines of force occurs; this change in turn induces an electromotive force in the conductor, which opposes the original current in the coil and tends to keep the current from rising.

Its action is similar to that which would take place if some extra resistance were suddenly inserted into the circuit at the instant the strength of the current is increased.

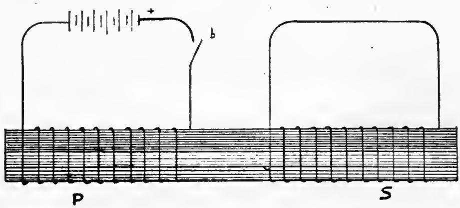
The original current eventually reaches its maximum strength in the coil as determined by Ohm's law, but its rise is not instantaneous; it is greatly retarded by this induced electromotive force.

If, on the contrary, the strength of the original current is suddenly allowed to decrease, another change is produced in the lines of force which pass through the conductor or coil; this new change induces an electromotive force which acts in the same direction as that of the original current and tends to keep it from falling.

As in the previous case, however, the original current will eventually drop to its maximum strength, as determined by Ohm's law, but will fall gradually and a fraction of a second will elapse before it becomes constant.

In short, the current flowing through a coiled conductor acts as possessing inertia; any sudden change in the strength of the current produces a corresponding electromotive force which tends to oppose that change and keep the current at a constant strength.

Mutual Induction.



In mutual induction two separate coiled conductors, one conveying a current of electricity, are placed near each other, so that the magnetic circuit produced by the one in which the current is flowing is enclosed by the other, as shown by the sketch, where the current circulates around the coil P when the circuit is closed at b. The coil P is called the primary or exciting coil, and the coil S is called the secondary coil.

Any sudden change in the strength of the current in the primary coil, as, for instance, breaking the circuit at b, a corresponding change in the number of lines of force in the magnetic circuit which passes through both coils; and hence, an electromotive force is induced in the secondary coil.

If the primary circuit is completed at b, and the current tends to rise in the coil, the electromotive force induced in the secondary coil, causes a current to circulate around it in the opposite direction to the current in the primary coil.

If, on the contrary, the circuit at b is suddenly broken and the current in the primary decreases, the induced electromotive force in the secondary coil causes a current to circulate around it in the same direction as the current in the primary coil.

The directions of an induced current in a coil depends upon the direction of the lines of force in the coil and whether their number is increasing or diminishing. If, then, two facts are known, the direction in which the current circulates around the coil is determined by the following rule:

Rule.—If the effect of the action is to diminish the number of lines of force that pass through the coil, the current will circulate around the coil from left to right, or clockwise, as viewed by a person looking along the magnetic field in the direction of the lines of force; but if the effect is to increase the number of lines of force that pass through the coil, the current will circulate around in the opposite direction.

Q. 63. (1900-01.) Give a convenient method for remembering the direction of a current generated in a straight conductor when the conductor is moved in a magnetic field at right angles to the lines of force.

As a summary of electro-magnetic induction experiments, what law is established?

Ans. 63. Rule.—Place the thumb, forefinger and middle finger of the right hand so that each will be perpendicular to the other two; if

the forefinger points in the direction of the lines of force, and the thumb points in the direction in which the conductor is moving, then the middle finger will point in the direction toward which the current generated in the conductor tends to flow.

The summary of these electro-magnetic induction experiments can be stated as follows: Electromotive forces are generated in a conductor moving in a magnetic field at right angles to the direction of the lines of force, or are induced in a coiled conductor when a change occurs in the number of lines of force which pass through the coil.

Q. 64. (1900-01.) To what is E. M. F. generated in a moving conductor cutting lines of force at right angles, directly proportioned?

Can you explain this principle by the use of cross-section paper?

Ans. 64. The E. M. F. generated in a moving conductor cutting lines of force at right angles is directly proportioned to the rate of cutting.

If, for an example, that a magnetic field contains 100,000 lines of force and a conductor is moved across the field at right angles in such a manner as to cut every line of force in one second, then the rate of cutting is 100,000 lines per second; if it occupied two seconds of time, then the rate of cutting would be 50,000 per second, and the electromotive force in this case would be one-half that of the former case.

Q. 65. (1900-01.) Explain the change in direction of the current in a coiled conductor moving in a magnetic field, and give value of this current at different points in one revolution.

Ans. 65. When the coil begins to revolve in the magnetic field, a feeble E. M. F. is generated; this E. M. F. causes a corresponding current to flow through the circuit in a positive direction; as the E. M. F. becomes larger, the strength of the current in the circuit becomes greater, and vice versa.

After the coil is rotated one-half of a revolution and the direction in which the E. M. F. tends to act becomes negative, the direction of the current in the circuit is also reversed.

If there is no self induction to retard the rise and fall of the current in the circuit the strength of the current in the circuit at any instant is exactly proportional to the E. M. F. that is being generated in the coil at that moment; for, according to "Ohm's" law, the strength of a current in any circuit is equal to the E. M. F. generated in that circuit, divided by its resistance.

The rising and falling and also the reversing of the current in all parts of the circuit can be graphically represented on cross-section paper.

In which the current at the starting point in each revolution is zero, rising to the maximum strength at one-quarter of the revolution, following again to zero at the one-half point of the revolution, at which point the current is reversed and again rising to its maximum strength at the three-quarter revolution, falling again to zero strength at the completion of the revolution, when, as at the one-half revolution or zero point, the current is reversed, showing that the strength of the current is at its maximum strength and at zero strength twice in each revolution. At intermediate points the strength of the current is proportional to the time required for making the full revolution.

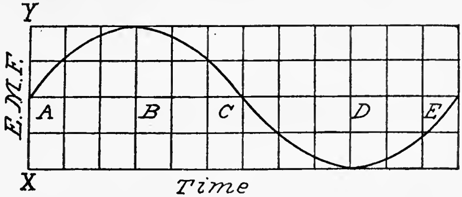
Q. 66. (1900-01.) Describe an alternating current.

Show by the use of cross-section paper the value of the E. M. F. in one complete revolution.

What is understood by the term "alternation"?

What is understood by the term "frequency"?

What is understood by the term "cycle"?
A "cycle" represents how many degrees?
How in regard to time?



DESCRIPTION OF SKETCH.

Ans. 66. The E. M. F. that is generated in a coil at every instant during one complete revolution is graphically shown in the sketch by the use of cross-section paper. (See sketch.)

The sum of the divisions between A and E represents the time occupied by the coil in making one complete revolution; the divisions between A and Y represent the E. M. F. which tends to send a current through the coil in one direction during the first half of the revolution, and the divisions between A and X represent the E. M. F. which tends to send a current through the coil in an opposite direction as in the last half of the revolution. The divisions between the curved line and the base line AE give the E. M. F. that is being generated in the coil at any instant during the revolution, and the direction in which the E. M. F. tends to act depends upon whether this E. M. F. is above or below the base line AE.

For convenience, let the direction of the E. M. F. in the first part of the revolution be called positive and in the last half negative.

For example, the E. M. F. that is generated in the coil when it has revolved three-quarters of a revolution is represented by the distance between D and the curved line, which in this case is two divisions; and, since these divisions are below the base line, the direction in which this E. M. F. tends to act is negative.

The time of one complete revolution is represented with sub-divisions A, B, C, D, E.

A B representing one-quarter revolution.
A. C. representing one-half revolution.
A D representing three-quarter revolution.
A E representing complete revolution.

The electric current as described in answer 65 is an alternating current.

The term Alternation. In each reversal of current—that is, each increase of current from zero to maximum and the decrease to zero again is called an alternation, thus two alternations occurring in one revolution.

This pair of alternations is called a cycle, and the number of cycles that occur in one second is termed the frequency.

A cycle represents 360°, regardless of time.

Q. 67. (1900-01.) What is meant by the term "commuting"?
For what purpose is a commutator used?
What is a "pulsating" current?
How can the strength of such current be made more uniform and pulsations less noticeable?
What is the effect of inserting an iron core between the poles of a magnet?

Ans. 67. The term commuting means to change, and for the subject which we are treating would mean to change an alternating current into a continuous current, for which purpose a commutator is used. A combination of two segments of copper insulated apart from each other, or, in fact, any number of segments constitute what is called a commutator.

Two or more copper or carbon brushes press against the segments and are held in the proper position while the coil is rotated.

The brushes rub or brush against the segments and make electrical contact only. By this arrangement the current in the external circuit flows continually in the same direction, while the current in the coil flows in two directions during every revolution. But the strength of the current in the external circuit is by no means constant. It rises from zero to maximum and falls again to zero twice in every revolution, but always in the same direction. This effect is produced continually in the external circuit if the coil is rotated at a constant speed. These impulses in the strength of the current give it the name of "pulsating current."

The strength of such currents can be made more uniform and the pulsations less noticeable by using more coils connected to segments in the commutator, the planes of the coils being placed at equal angles from each other.

In last year's treatment of this subject the term permeability was defined as the facility afforded by any substance to the passage through it of lines of force, and that permeability of soft iron may be in the ratio of 2,000 to 1 as compared to air; and that when a magnetic substance is brought into a magnetic field the lines of force in the field crowd together and all try to pass through that substance, etc.

Hence, if the coils are wound around a cylindrical drum of iron the number of lines of force passing through the coils is increased.

These coils are entirely insulated from the iron core by some non-conducting material, otherwise they would be short circuited on the core—that is, the current would pass through the iron instead of passing into external circuit.

An iron core inserted between the poles of a magnet not only increases the lines of force from the magnet, but attracts nearly all the stray lines of force from the surrounding air.

Q. 68. (1900-01.) In a rotated coil, where will the greatest difference in potential be found?

What means are used to utilize this difference of potential between each pair of wires?

If a comparatively large number of turns and segments are used, what will be the effect of the current? Why?

Ans. 68. In a rotated coil the greatest difference in potential will be found between any two turns diametrically opposite one another when they pass through the vertical diameter. To utilize this difference of potential between each pair of turns as they arrive in a vertical position.

This is accomplished by connecting each turn to a separate segment of a commutator by a small conductor and allowing two brushes to rub against the commutator at two points diametrically opposite each other on the vertical diameter.

If a comparatively large number of turns and segments are used the current flowing through the external circuit will practically be continuous—that is, non-pulsating; the fluctuations caused by the brushes passing from one segment to another are extremely minute and produce no appreciable change in the strength of the current in the external circuit.

Q. 69. (1900-01.) Describe a closed coil winding.
Describe an open coil winding.
What is meant by neutral spaces?
What is meant by neutral points?
Explain shifting of brushes, etc.

Ans. 69. Closed Coil Winding. A conductor wound upon a core in this manner is termed a "closed" coil winding, since all the turns are connected together in one continuous or closed coil and the current is obtained from it by lapping into each turn or set of turns.

In the case where the turns or set of turns are separate and distinct from each other and their ends are connected to opposite segments of a commutator the winding is termed an "open" coil winding.

The parts of the core where the conductors are not cutting lines of force as the core is rotated are called "neutral spaces."

The two opposite parts of the commutator to which the coils are connected are called the neutral point of the commutator.

Each individual conductor in a bipolar machine becomes inactive twice in each revolution and passes through two neutral spaces; but this fact does not change the position of the neutral spaces—they lie on an imaginary diameter approximately perpendicular to the lines of force.

This same effect takes place in the commutator—i. e., each segment passes through two neutral spaces during one revolution, but the neutral points remain in a fixed position relative to the neutral spaces of the core.

The neutral segments of a commutator, at any instant during a revolution, are those segments connected to the conductors passing through two neutral spaces at that instant.

The neutral points can be shifted to different points around the commutator by changing the leads from the coil to the segment.

In order to collect any current from the commutator the brushes must be at the neutral points.

The current flowing through the winding divides at the neutral space and flows through the coil in opposite directions, uniting again at the other neutral space.

Q. 70. (1900-01.) Suppose a magnetic field contains 25,000,000 lines of force and a conductor cuts the total number in the same direction in one second. What will be the generated E. M. F.?

Suppose there were 25 conductors connected in series, cutting the lines of force at equal rates (as above), what will be the generated E. M. F.?

Suppose in the latter case that the 25 conductors were moved across this same magnetic field at the rate of 40 times per second, what would be the generated E. M. F.?

What application of formula can be made in relation to a closed coil conductor, wound upon a ring or drum core?

Ans. 70. In the case of a single conductor moving across a magnetic field in which the total lines of force is known, the rate of cutting is equal to the total number of lines of force cut by the conductor divided by the time required to cut them.

This may be expressed in the form of an equation, thus the rate of cutting $= \frac{N}{t}$, where $N =$ the total lines of force cut and $t =$ the time required to cut them.

By definition: One volt is that E. M. F. generated in a conductor when it is cutting lines of force at the rate of one hundred million (100,000,000) per second.

Hence $E = \frac{N}{10^8 t}$ when E is the E. M. F. in volts; t = the time in seconds; $100{,}000{,}000 = 10^8$.

For example, a magnetic field contains 25,000,000 lines of force, and the conductor cuts the total number in one direction in one second, according to our formula.

$$\text{The generated E. M. F.} = \frac{25{,}000{,}000}{100{,}000{,}000 \times 1} = .25 \text{ volt.}$$

If there were 25 conductors moving across the magnetic field under the same conditions as in previous question, then will the generated

$$\text{E. M. F.} = \frac{25{,}000{,}000 \times 25}{100{,}000{,}000 \times 1} = 6.25 \text{ volts.}$$

If the 25 conductors were moved across the same magnetic field 40 times per second,
the generated E. M. F.

An equation representing this operation is

$$E = \frac{(Nnt)\ S}{10^8 t} = \text{eliminating "t," } E = \frac{NSn}{10^8}$$

In which—
N = number of lines of force.
n = number of times per sec. one conductor cuts the lines of force.
t = time in seconds.
S = number of conductors.

This equation can be applied with some modifications to the closed coil conductor wound upon either the ring or drum core.

In case of the ring core, E in the equation represents the maximum E. M. F. in volts that is obtained from the positive and negative brushes when the core is revolved.

N is the total number of lines of force passing from the north pole through the core to the south pole (bi-polar dynamos).

Each wire, therefore, on the periphery of the core, cuts the total number of lines of force twice in each revolution, or, in other words, outside wire cuts 2N lines of force per revolution.

S represents the number of outside wires on the periphery through which the current flows in series, and n is the number of complete revolutions per second of the core.

Therefore, the maximum E. M. F. in volts that is obtained from the brushes is found by the formula—

$$E = \frac{2NSn}{10^8}$$

This formula holds equally true for the drum core.

In both cases the number of outside wires through which the current flows in series is equal to one-half of the total number of outside wires. Hence, by using the same magnetic field and rotating the cores at equal speed, the E. M. F. generated in both cases will be equal.

The difference of potential between the brushes when the external circuit is closed is somewhat smaller than where no current is flowing; the same as in the case of the voltaic cell, a part of the total E. M. F. developed is required to overcome the internal resistance.

Q. 71. (1900-01.) The foregoing questions treat upon the elementary principle and physical theory of a dynamo.
What is a dynamo?
What are its three most essential features?
In all dynamos, how is the magnetic field produced?

Ans. 71. A dynamo is a machine for converting mechanical energy into electrical energy by electro-magnetic induction.

The three essential features are:

First, a magnetic field.

Second, a conductor or several conductors, called an armature, in which the electromotive force is generated by some movement relative to the lines of force in the magnetic field.

Third, a commutator or collector from which the current is collected by two or more conducting brushes.

In all dynamos the magnetic field is produced either by a permanent magnet or by an electro magnet, and they are classified accordingly.

For our purpose, however, it is sufficient to consider only the uniform magnetic field lying between the poles of some large magnet.

Q. 72. (1900-01.) Give general rule for a conductor conveying an electric current when placed in a magnetic field.

Give a convenient rule for remembering the direction of motion imparted to a conductor conveying an electric current when placed in a magnetic field.

If a vertical conductor in which a current is flowing downward, is placed in front of the north pole of a magnet, in which direction will the conductor tend to move?

Ans. 72. When a conductor conveying an electric current is placed in a magnetic field, the conductor will tend to move in a definite direction and with a certain force, depending upon the strength and direction of the current and upon the direction and density of the lines of force in that field.

Rule.—Place thumb, forefinger and middle finger of the left hand each at right angles to the other two; if the forefinger points in the direction of the lines of force and the middle finger points in the direction toward which the current flows, then the thumb will point in the direction of movement imparted to the conductor.

In the case of a vertical conductor in which the current is flowing downward and is placed in front of the north pole of a magnet the conductor will tend to move from left to right.

Q. 73. (1900-01.) Compare rule given in question 63 and the rule given in question 72 and explain the opposition seemingly of one to the other in the direction of current.

Explain the theory of counter torque of a dynamo.

Ans. 73. Comparing the previous rules with the one just given, it will be seen that the two appear to oppose each other; or, in other words, the current which flows in the former case, according to the latter rule, tends to oppose the motion of the conductor and move it in the opposite direction.

This is exactly what takes place.

When a conductor is moved across the lines of force, an electric current is generated, which tends to send a current in a definite direction.

If the circuit is open and no current flows, it requires no force to move the conductor across the field; but if the circuit is closed and a current flows through the conductor, then the action of the lines of force on the current opposes the original motion and tends to stop or retard the conductor.

The opposing force is proportional to the strength of the current flowing in the conductor. But, so long as the conductor is moved, the applied force is always larger than the counter force.

Hence the stronger the current in the conductor the greater will be the force necessary to keep the conductor moving in the original direction. The counter force would never actually move the conductor in

its direction, but it exerts a dragging effect upon the conductor which would reduce its speed and almost stop its motion, if the exterior motive force is not increased.

The above principles explains the action of converting the mechanical energy into electrical energy in a dynamo.

If an armature is properly wound and connected to a commutator, an electromotive force is generated in the outside conductors on the core, causing a difference of potential between the brushes. If the brushes are not connected to an external circuit and no current is flowing through the armature, it requires no energy to rotate the armature, excepting a small amount to overcome the mechanical friction and the loss in the armature iron by eddy currents.

If, however, connected to an external circuit and a current flowing through the armature the conditions are changed.

The lines of force react upon the current in the conductors, tending to rotate the core in an opposite direction and to retard its motion; the stronger the current the greater the retarding effect.

Hence, to keep the speed constant and to generate a constant E. M. F., more energy must be supplied.

This retarding effect of the current is known as the "Counter Torque" of a dynamo.

Q. 74. (1900-01.) Can it be mathematically proven that the mechanical energy delivered to the armature from any exterior source is exactly equal to the electrical energy obtained from the armature plus the energy lost in mechanical friction, eddy currents in the iron and other small losses?

What are the losses that occur in an armature?

How can the effect of armature reaction be almost entirely eliminated?

Ans. 74. It can be mathematically proven that the mechanical energy delivered to an armature from any exterior source is exactly equal to the electrical energy obtained from the armature plus the energy lost in mechanical friction eddy currents in the iron and other small losses.

Besides producing a counter torque in the armature, the current tends to distort or crowd the lines of force from their original position in the magnetic field. This effect is termed armature reaction. The greater part of the electrical energy is transmitted to the external circuit, while the rest of the energy, usually the smaller portion, is converted directly or indirectly into heat energy in different parts of the dynamo itself.

The principal armature loss is that produced by the current flowing against the internal resistance of the armature, that is the resistance of the conductors.

The core loss, is the energy converted into heat in the iron discs of the armature core when they are rotated in a magnetic field.

A small portion of this loss is due to eddy currents generated in the revolving core discs. A large portion is due to magnetic friction which occurs whenever the direction of the lines of force is rapidly changed in a magnetic substance.

This effect is termed "Hysteresis."

The energy expended by hysteresis is furnished by the force which causes the change in the magnetism; and in the case of an electromagnet when the magnetism is reversed by the magnetizing current, the energy is supplied by the magnetizing current.

The same effect is produced when the iron of the armature core is rapidly rotated in the constant magnetic field.

This case differs from the electro-magnet only in the fact that the magnetic lines of force remain at rest and the iron core is made to rotate.

Since the core is rotated from the armature shaft, the energy lost in hysteresis is furnished by the force which drives the shaft. In well designed dynamos the core loss should not exceed 2% of its input when delivering its rated output from the brushes.

The total per cent losses in armatures of constant potential dynamos varies from about 12% of the input to dynamos having a capacity of 1,000 watts to as low as 1.5% to 2% of the input of dynamos of rated capacity of about 100,000 watts and upwards.

Armature reactions not only distort the magnetic field, but also have a tendency to reduce the total number of lines of force from the magnet and thereby diminish the E. M. F. generated in the armature.

This effect, however, can be almost entirely eliminated by increasing the strength of the field; or in other words, increasing the number of lines of force passing through the core.

Q. 75. (1900-01.) What is meant by the term separately excited dynamos? Elucidate.

Explain the term magnifying force and ampere-turns.

Are the number of lines of force directly proportional to the number of ampere-turns.

Why?

What metals should be used in field magnets and why?

What is meant by magnetic saturation?

What is the limit for practical saturation in different kinds of iron?

What is the effect if this limit is exceeded? In general, how are the field coils or magnets designed?

Ans. 75. A separately excited dynamo is one in which the field coils are excited from some exterior source; as, for instance, a voltaic battery, or another continuous current dynamo.

The magnetizing coils are wound around the cores of the field magnet in such direction as to produce a closed magnetic circuit through the armature and has no connection whatever with the current obtained from the brushes by rotating the armature.

If the strength of the exciting current is not changed, the difference of potential between the brushes of the dynamo when the armature is rotated at a uniform speed, remains constant so long as the external circuit is open; but when the external circuit is closed, the difference of potential gradually diminishes as the strength of the current increases, owing to the internal resistance of the armature conductors and the reactions of the armature current in the fields.

The magnetizing force is that which produces the lines of force in the magnet. Its strength is proportional to the strength of the current flowing, and to the number of coils, or complete turns around which the current circulates.

The total number of turns multiplied by the strength of the current in amperes will give the magnetizing force in ampere turns.

The number of lines of force produced in an electro-magnet is not directly proportional to the magnetizing force in ampere turns.

The strength of the magnet in lines of force depends upon the permeability of the magnetic substance used in the core.

In general, wrought iron, soft sheet iron, and steel have greater permeability than cast iron and, whenever available, should be used in field magnets.

A substance has reached a state of magnetic saturation when it has absorbed all the lines of force it can hold. A limit is never reached when actual saturation takes place, but there is a limit beyond which it becomes impracticable to magnetize a substance.

In all kinds of magnetic substances, the permeability decreases when the magnetism is increased beyond a certain limit. Practical saturation in wrought iron, soft sheet iron and cast steel, is when there are 120,000

and 130,000 lines of force per square inch of the iron measured on a plane at right angles to the lines of force in the magnet.

If these limits are exceeded, it requires an enormous increase in the ampere turns to produce a slight change in the number of lines of force in the magnet.

In general, however, the field magnets of dynamos are designed with the density of the lines of force below the saturation limits, and it is safe to assume that any change in the strength of the current circulating around the magnetizing coils produces a corresponding change in the number of lines of force passing through the magnetic circuit.

Consequently, if the strength of the current in the field coils of a separately excited dynamo is increased as the current in the armature becomes stronger, the E. M. F. obtained from the brushes will remain practically constant.

This is usually accomplished by inserting an adjustable resistance box or field rheostat in the series with the battery and field coils.

Decreasing the resistance as the load increases or as the difference of potential between the brushes tends to drop.

Q. 76. (1900-01.) What is meant by the term "self-exciting" as applied to a shunt dynamo?

In well designed dynamos how is the resistance of the field coils so proportioned that a proportional part of the total output of current will pass through the field coils?

Explain the term "residual magnetism."

What is the effect in the building up of the E. M. F.?

What is the effect upon the difference of potential between the brushes of a shunt dynamo as the armature current becomes stronger?

How is this effect compensated for?

Ans. 76. A self-exciting dynamo, or simply a shunt dynamo, is a dynamo in which the magnetizing of field coils are excited from the current furnished by the dynamo itself, the field coils being connected in shunt with the external circuit from the brushes.

One terminal of the magnetizing coil is connected to the negative brush and the other to the binding post in the field rheostat; the positive brush is connected to the arm of the rheostat.

If the resistance of the rheostat is cut out it will be seen that the total difference of potential exists between the terminals and the magnetizing coils when the dynamo is generating its maximum E. M. F.

The magnetizing coils of a shunt dynamo, however, consists of a large number of turns of fine copper wire, thus making the resistance large in comparison with the difference of potential between the field terminals. In well designed dynamos the resistance of the shunt coil is large enough to allow not more than 5 % of the total current of the dynamo to pass through the field coils.

Permanent magnetism is called "Residual Magnetism," since it resides in the metal after the magnetizing force has been removed. Soft iron and annealed steel retain only a small amount of magnetism. Chilled iron and hardened steel retain residual magnetism in large quantities.

When a shunt dynamo is rotated at a constant speed, an appreciable length of time elapses before the armature generates a maximum E. M. F. after the field circuit is closed and in some cases, a self-exciting dynamo will generate no current until after it has been once separately excited.

The starting of a dynamo to generate an E. M. F. is termed the picking-up or building-up.

If the field coil is open so that no current flows through the magnetizing coil, the armature will not generate any E. M. F. when rotated; providing, however, that the field magnets were not permanent magnets.

The difference of potential between the brushes of shunt dynamos gradually decreases as the armature current increases or becomes stronger on account of the internal resistance of the armature conductors and the reaction of the current on the field.

To compensate for this decrease in the E. M. F., a field rheostat of comparatively high resistance is connected with the field circuit and so adjusted that when no current is flowing in the external circuit, only enough current flows through the field to produce the normal difference of potential between the brushes; this normal difference of potential between the brushes is kept constant, as the load increases, by gradually cutting out or short-circuiting the resistance coils of the rheostat.

Q. 77. (1900-01.) Explain a "series dynamo."

Explain first how the action of a series dynamo differs widely from a shunt dynamo.

In the second place, upon what does the difference of potential depend?

What comparison in the coils between the two machines can be made and why is this necessary?

How is a series dynamo regulated?

How many methods are there employed?

How is this regulation sometimes made automatic?

Can this regulation be accomplished in the dynamo itself? If so, what is this style of a dynamo called?

Ans. 77. The series dynamo is one where the magnetizing coils are connected directly in series with the external circuit; that is, all the current from the armature circulates around the magnetizing coils before passing through the external circuit.

The action of a series dynamo differs widely from the shunt dynamo. In the first place, no E. M. F. is generated in the armature unless the circuit is closed and flows from the brushes; that is, neglecting the small E. M. F. generated, due to the residual magnetism.

In the second place, the difference of potential between the brushes depends upon the strength of current flowing from the armature.

The E. M. F., however, is not directly proportional to the strength of the current unless the internal resistance and reactions are excessive.

Compared with the coils of a shunt dynamo, the magnetizing coils of a series dynamo are made with a few turns of a large conductor.

This is necessary because the coils usually are required to carry the total current of the armature; and the conductor is made large enough to carry the current without heating, and only a few turns are necessary to secure the proper magnetizing, since that is proportional to ampere turns.

The E. M. F. of a series dynamo is regulated in three different ways—viz.:

(1) By controlling the strength of the current in the external circuit, as has been described.

(2) By short-circuiting, or cutting out part of the magnetizing coils.

(3) By shunting part of the current around the magnetizing coils.

These methods of regulation are not, however, automatic; it is, however, accomplished by a mechanical movement of an arm or contact. This movement is sometimes imparted by a magnet controlled by the current from the armature, but more often the E. M. F. is automatically regulated in the dynamo itself by a combination of shunt and series magnetizing coils.

Such dynamos are called compound or shunt and series dynamos.

Q. 78. (1900-01.) Describe a "compound dynamo."

What effect has the series coil winding upon the difference of potential between the brushes?

What is this method of regulating the difference of potential between the brushes called?

How are the terminal of a compound dynamo attached to the windings, also to the outside circuit?

What is meant by the term "over-compound?"

The expression, "per cent over-compound?"

What are machines having one pair of poles called? More than one pair called? What are salient poles? What are consequent poles?

Ans. 78. The compound dynamo, the shunt coils, consist of a large number of turns of fine insulated wire, wound upon the core of the magnet.

The series coils consist of a few turns of large insulated wire and are either wound over the shunt coils or placed directly on the core itself either above or below the shunt winding; this latter manner of winding is preferable on account of repairs.

The main part of the current from the armature flows from the positive brush through the external circuit thence through the series coil to the negative brush.

The two terminals of the shunt coils are connected to the positive and negative brushes with a rheostat in series.

The action of both currents of the series and shunt coils must be in the same direction around the coils to produce the same polarity in the magnet; the series current reinforcing the shunt current.

When the dynamo is not loaded and the armature is rotated at nominal speed, the normal E. M. F. generated is due to the magnetic field produced by the shunt coils alone.

Upon closing the external circuit, however, the difference of potential between the brushes tends to decrease and would so continue to decrease as in the shunt machine if the series coils were not called into action.

The current circulating around these, however, reinforces the magnetizing force of the shunt coils and immediately increases the lines of force in the field which in return raises the potential between the brushes to normal. These actions are produced simultaneously and, to all appearances, the difference of potential between the brushes remains normal for all changes of load in the external circuit. This method of regulating the E. M. F. of a dynamo is called "Compounding."

The terminals of a dynamo are the binding posts to which the external circuit is connected; in a series or compound dynamo one terminal is attached to the outside end of the series coil and the other is connected directly to the brush.

It is desirable in a great many cases to over-compound a dynamo; that is, by adding a sufficient additional number of turns in the series winding so as to increase the difference of potential between the brushes above the normal when the load increases.

This increase in E. M. F. is usually expressed in per cent over-compound.

Machines having one pair of poles are called "Bi-polar" machines.

Machines having more than one pair are called "Multi-polar" machines.

Salient Poles.—In all cases where a single coil is used, or where if two coils are used both wound in the same direction, the poles are called salient poles.

Consequent Poles.—Where two coils are used and wound in opposite directions they are called consequent poles.

Q. 79. (1900-01.) Into what three general types, depending on the character of their currents, are dynamos divided? Describe them.

In constant potential dynamos and generators, describe the windings of the pole pieces or field core and the direction of the lines of force, etc.

Why are four brushes or more needed on a multi-polar machine?

How is the regulation of multi-polar machines accomplished?

Ans. 79. Dynamos are divided into three general types, depending upon the character of their currents.

(1) "Constant potential dynamos," in which the E. M. F. remains constant and the strength of the current (continuous) changes with the load.

(2) "Constant current dynamos," in which the strength of the current (continuous or pulsating) remains constant and the E. M. F. changes with the load.

(3) "Alternating current dynamos," the current from which alternates or reverses direction with great rapidity.

The previous questions and answers have demonstrated the principles and regulations of only one form of constant potential dynamos that, in which an armature was rotated between only one pair of poles. Theoretically, however, constant potential dynamos can be built with an armature revolving between any number of pairs of poles. Such machines are termed multi-polar dynamos.

In multi-polar dynamos, the pole-pieces and field cores are fastened into one magnetic yoke more or less circular in shape.

A magnetizing coil is wound upon each field core and the four coils are connected in series in such a manner that when the current circulates around the coil it produces first a north pole and then a south pole.

The lines of force from each field core divide into two magnetic circuits in the yoke and armature.

Their density is practically uniform, however, when they pass from the north pole into the armature core, or from the armature core into the south pole.

In nearly all multi-polar dynamos this same principle of polarity is applied; that is, every other pole piece is of like polarity and lines of force from each core divide into the magnetic circuit, in the armature and in the field yoke.

The process of generating and E. M. F. is similar to that in a bipolar machine, but there are some points which should be understood.

In the case of a four-pole, ring-core closed-winding machine, by tracing out the direction in which the E. M. F. tends to act upon the conductors, it will be seen that there are four points where the E. M. F. tends to act in opposite directions. The action of the electromotive forces is to meet between one pair of poles and divide between the next pair, etc., and the segments at the two points of meeting have the same potential and form two positive neutral points of the commutator, while those segments at the point where the current divides form the two neutral points of the commutator. Hence the necessity of four brushes, two positive and two negative. The two positive brushes being connected in parallel to one terminal of the external circuit and the two negative brushes are connected to the other terminal of the external circuit.

It is possible, however, to connect and group the conductors in an armature for a multi-polar dynamo so that the current will divide into two circuits only, this winding is termed a series winding.

The regulation of multi-polar dynamos for constant potential is accomplished by changing of the strength of the magnetizing force as in the bi-polar machines.

core and all connected together in parallel, or series, as is most convenient.

Q. 80. (1900-01.) What is meant by the efficiency of constant potential dynamos?

In a compound dynamo, the series coils are wound on each field

What is the mechanical energy delivered to the armature shaft called?

To what is it equal?

What is the electrical energy appearing in the external circuit called?

To what is it equal?

What is the energy converted into heat, directly or indirectly, called?

How would you find the per cent efficiency of a dynamo?

How would you find the total per cent loss of a dynamo?

Upon what does the efficiency of a dynamo depend?

How would you find the input necessary to drive a dynamo when its output and efficiency at that output are given?

How would you find the output of dynamo when its input and its efficiency at that input are given?

Name the four classes into which the total loss of power in a dynamo, ordinarily is due to.

Describe each, briefly.

Ans. 80. If in converting or transforming a certain amount of mechanical energy into electrical energy, the energy which is manifested in one form disappears, and the same quantity appears in another form, or in several different forms, then the amount of energy delivered at the armature shaft is always equal to the energy appearing in the external circuit, plus the energy converted into heat in the dynamo itself.

The mechanical energy delivered to the armature shaft is termed the input.

The input is always equal to the output at the brushes plus the losses in the machine itself.

The electrical energy appearing in the external circuit from the brushes is termed the output.

The output plus the energy lost in the dynamo itself is equal to the input.

Energy lost or converted into heat is termed energy losses or simply losses.

To find the per cent efficiency of a dynamo:

Rule.—Multiply the output in watts by 100 and divide the product by the input in watts.

To find the total per cent loss in a dynamo:

Rule.—Multiply the difference in watts between the output and the input by 100 and divide this product by the input in watts.

The efficiency of a dynamo depends upon its character, construction, condition when tested, its capacity, losses and various conditions; in fact, two dynamos of the same construction and capacity seldom show exactly the same efficiencies.

To find the input necessary to drive a dynamo when its output and its efficiency at that output is known:

Rule.—Divide the output in watts by the per cent efficiency and multiply the quotient by 100.

To find the output of a dynamo when its efficiency is known at that input:

Rule.—Multiply the input by the per cent efficiency and divide this product by 100.

(1) Mechanical friction loss.
(2) Core loss.
(3) Field loss.
(4) Armature loss.

Friction loss, due to mechanical friction which takes place between the bearings and journals. The brushes rubbing on the commutator produce some friction, and consequent loss. Under ordinary conditions

the loss in mechanical friction should not exceed 5% of the input of the dynamo.

Core losses is the energy converted into heat in the iron discs when they are rotated in the magnetic field. A small portion of this loss is due to eddy currents generated in the revolving core. The larger portion of this loss is due to a magnetic friction which occurs whenever the direction of the lines of force is rapidly changed in a magnetic substance. The effect produced by this rapid change in direction of the magnetizing current, the iron or steel of the core becomes heated which necessitates a certain amount of expenditure of energy. This effect is called hysteresis.

In a well designed dynamo the core loss should not exceed 2% of its input when delivering its rated output from the brushes.

Field Losses.—In self-exciting dynamos a portion of the electrical energy generated in the armature is required for the excitation of the field magnets.

This energy is considered as a loss, since it does not appear in the external circuit and is entirely dissipated in the form of heat.

The per cent loss in the field coils of dynamos varies from 10% of the input to dynamos having an output of 1,000 watts to as low as 1.5% to 2% of the input of dynamos having an output 100,000 watts and upwards.

The armature loss proper is usually termed the copper or wire loss, and is produced by the current flowing against the internal resistance of the armature.

The per cent loss in armatures of constant potential dynamos varies from 12% of the input of dynamos having a rated capacity of about 1,000 watts, to as low as 1.5% to 2% of the input of dynamos having the rated capacity of about 100,000 watts and upwards.

Technical, Mathematics, Science, Mechanics, Physics, Etc.

Q. 10. (1896-7.) How to find velocity of water in a pipe, knowing the pressure?

Ans. 10. Formula:—

$$Vm=2.315\sqrt{\frac{h\ d}{fl.+.125d}}$$

in which Vm = mean velocity.
h = total height in feet.
l = length of pipe (straight).
d = diameter of pipe.
f = coefficient of friction.

The pressure being given it is reduced to head by dividing the pressure by .434.

Assume:
h = 300 ft.
l = 100 ft.
d = 6″.
f = .0214.

Then: substituting

$$Vm=2.315\sqrt{\frac{300\times 6}{.0214\times 100+.75}}$$

$$=2.315\sqrt{\frac{1800}{2.89}}$$

$$=2.315\times 24.9=57.6435 \text{ ft. per second.}$$

[The constant 2.315 is the product of several factors that enter into the calculation and are calculated once for all in forming the constant. These factors are:

$$\frac{g\,x\,k}{\sqrt{144}}=\frac{32.\times .862}{12}=2.315$$

g = gravity, 32.2.
k = vena contracta, the reduction in the diameter of the stream of water after it leaves the end of the pipe, or nozzle.
12 = square root of 144, because some of the factors in this equation are given in feet and the square root of 144 shows the relation between "inches diameter" and "feet diameter," giving the proportionate area.]

Q. 15. (1896-7.) How to find the area of a segment?

Ans. 15. Divide the diameter of the circle by the height of the segment, subtract .608 from the quotient and extract the square root of the remainder. This result multiplied by four times the square of

the height of the segment and divided by three will give the area, nearly. Ex.:

$$\frac{4\,h^2}{3}\left(\sqrt{\frac{d}{h}}-.608\right)=\text{area.}$$

h = height of segment.
d = diameter of circle.

Q. 19. (1896-7.) What is momentum?

Ans. 19. Product of mass × velocity.

Q. 24. (1896-7.) Can water be evaporated with exhaust steam of atmospheric pressure, and if so, how?

Ans. 24. Yes; provided the pressure upon the water be kept below that of the atmosphere; in other words, under a vacuum. The lower the pressure or the greater the vacuum, the more rapid will be the evaporation.

Q. 26. (1896-7.) Is steam at thirty lbs. pressure absolute or air at sea level, the heavier?

Ans. 26. Little difference; air being 13.141 cubic feet to the pound, and steam 13.480 cubic feet to the pound, assuming the air to be dry and at the standard temperature, 62° F.

Q. 27. (1896-7.) What is the expansion of a wrought iron pipe 75 ft. long, erected at an external temperature of 20° F., and then charged with steam at 100 lbs. gage pressure?

Ans. 27. Temperature of steam 100 lbs. pressure is 337.7°. Co-efficient of expansion for wrought iron is .0000067302. Then 337.7 — 20 = 317.7, and 75 × 12 × 317.7 × .0000067302 = 1.924″.

Q. 28. (1896-7.) How determine the pressure per square inch at the base of a water column 125 ft. high?

Ans. 28. Generally speaking, the pressure in pounds per square inch equals head in feet × .434. To be accurate, however, the temperature of the water should be taken into account and the constant for such will be:

$$\frac{\text{Wgt. of cu. ft. water at obsv'd temp.}}{144}$$

Then, 125 ft. × .434 = 54.25 lbs.

Q. 33. (1896-7.) How many foot pounds of work required to change one pound of water at 32° F., into steam at 212°?

Ans. 33. The sensible heat to raise one pound of water from 32° to 212° is 180.9 heat units. The latent heat of evaporation at 212° is 965.7 heat units and the sum of the two, or total heat, is 1146.6 heat units. Since one heat unit equals 778 foot-pounds of work, there will be required to change one lb. of water at 32° into steam at 212°, 1146.6 × 778, or 892054.8 foot-pounds of work.

Q. 35. (1896-7.) Name the five most famous modern steam engineers.

Ans. 35. Watt, Stephenson, Evans, Rankine, Corliss (probably Newcomen, Fulton, Fairbairn and Ericcson, or some names from non-English speaking countries should be included). I have purposely avoided naming any men living at this day.

Q. 36. (1896-7.) What is adiabatic expansion?

Ans. 36. Adiabatic expansion is the curve formed by a perfect gas without loss of heat or transmission to or from the same.

Q. 45. (1896-7.) Will the pressure per sq. in. on two columns of the same liquid, of equal height but different diameters, be the same?

Ans. 45. The pressure per square inch of a column of liquid depends on its height and temperature, and is not affected by its diameter, and therefore the two columns, as contemplated in the problem, have equal pressures. If they stand close together this is so, but if one be at the equator and the other at the pole of the earth there will be a difference, owing to the effect of gravity. The one having the greater sensible heat, and therefore the lesser specific weight, will show the lesser pressure. If one be very much smaller than the other, cohesion of the retaining walls and attraction for same may lessen the pressure of the smaller column. This is more particularly true when the diameter of the column is very small, say the fractional part of an inch. Unusually thick and dense retaining walls about the column may also act as a cliff or wall does upon a plumb-bob, and, by exerting a side pull, lessen the downward effect of the column of liquid. Foreign particles in suspension or solution in the liquid may reduce or increase its weight and pressure.

Q. 49. (1896-7.) What abundant metal of commerce has the highest thermal conductivity?

Ans. 49. Copper, which excels all other metals but silver in conductivity of heat, and because silver is not properly an abundant metal.

Q. 53. (1896-7.) What is work?

Ans. 53. Work is the overcoming of resistance through space or through a certain distance. It is measured by the product of the resistance into the space through which it is overcome. It is also measured by the product of the moving force into the distance through which the force acts in overcoming the resistance. Thus, in lifting a body from the earth against the attraction of gravity, the resistance is the weight of the body and the product of this weight into the height the body is lifted is the work done.

Q. 56. (1896-7.) What is heat?

Ans. 56. Heat is not a substance, but is a form of energy. Heat is treated in scientific books under the heading "Thermo-Dynamics," from two Greek words, signifying heat power. The word "heat" is commonly used in two senses—first, to express the sensation of warmth; second, the state of things in a body that causes that sensation.

Heat, as a form of energy, is subject to the general laws governing every form of energy and controlling all matter in motion, whether that be molecular, or movement of the mass. Heat is not a substance. It can be absorbed and reflected the same as a ray of light. It can be conducted through a substance or between two bodies in contact. When-

ever there exists a difference in temperature between two bodies, and particularly if in proximity to each other, there is a tendency to an exchange of heat and an equalization of temperature.

Heat, like other energy, cannot be destroyed, but can be altered in form.

Heat usefully employed plus that lost or wasted always equals in amount the total heat applied.

Heat and temperature must not be confused with each other. A dipperful of water and a pailful may be of the same temperature and yet contain very different total amounts of heat. Quantity of heat in a body depends upon the mass, temperature and specific heat of the substance. Heat can be produced or brought into evidence by physical or chemical forces, and may be a measure thereof—being always proportional to the effort expended.

Q. 58. (1896-7.) What is the latent heat of steam? Explain how it may be found.

Ans. 58. Latent heat of steam is the quantity of heat which disappears or becomes concealed in it while producing some change in it other than a rise in temperature. By reversing this change, the quantity of heat which had disappeared will be reproduced. It may be observed that heat disappears when water passes from the liquid to the gaseous state. At 212° temperature this has been determined by experiment to be nearly 966 units of heat. From 212° to 32° there are 180 heat units absorbed; then $966 \div 180 = 5.37$ times as much heat needed to convert water into steam as is required to raise its temperature to the boiling point. To find latent heat of steam, multiply the sensible heat by .3, add 1115°, and we get the total heat, from which we subtract the sensible heat to find the latent heat.

Q. 66. (1896-7.) At what temperature are carbonates and sulphates of lime practically all deposited from feed waters?

Ans. 66. Carbonates of lime are practically all deposited from feed water at 212° F.; sulphate of lime at about 280° F. to 300° F.

Q. 67. (1896-7.) What is meant by sublimation?

Ans. 67. To use the term literally and chemically sublimation is an operation by which a solid body is changed by heat into vapor and then condensed into a solid form again, without changing into a liquid. To use it figuratively, it is the act of heightening, refining and exalting that which is highly refined, purified or improved. Sublimate (chemically)—the result of the process of sublimation—a body obtained in the solid state by the cooling of its vapor. For example, iodine, sal-ammoniac, mercuric chloride (corrosive sublimate), camphor, etc.

Q. 70. (1896-7.) What is isothermal expansion?

Ans. 70. Isothermal expansion is the application of what is known as Mariotte's law of the expansion of gases—that the volume of all elastic gases and vapors is inversely as the pressure. Thus, if a given volume be allowed to expand to two such volumes, the pressure will be reduced one-half; if to three volumes, to one-third, and so on. If compressed, the pressure will rise in proportion to the reduction of volume.

This law is found to be correct only when expansion takes place at constant temperature, and is therefore called "isothermal (equal temperature) expansion."

Q. 74. (1896-7.) What is the final temperature of a mixture of 3 lbs. of ice at 10° F., with 20 lbs. of water at 60°, there being no loss of heat?

Ans. 74. The specific heat of ice is .504. Heat of liquefaction of ice is 142.65. Heat required to bring 1 lb. of ice from 10° to 32° = 32 — 10 = 22 units. 22 × 3 × .504 = 33.264 heat units.

Heat units required to convert ice at 32° into water at 32° is 142.65 × 3 = 427.95.

Total heat needed to convert 3 lbs. ice at 10° into water at 32° = 427.95 + 33.264 = 461.214 units.

Total heat in 20 lbs. water at 60° = 20 × 60 = 1200.

Total heat in 3 lbs. water at 32° = 3 × 32 = 96.

Total, 1296 heat units.

The total sensible heat in the mixture would be 1296—461.214 = 834.768 units.

834.768 ÷ 23 (20 + 3) = 36.295°, temperature of the mixture.

Q. 75. (1896-7.) What is meant by the external and internal latent heat of steam?

Ans. 75. The total heat in steam includes three elements:

1. Heat required to raise the temperature of the water to the temperature of the steam.

2. Heat required to evaporate the water at that temperature called the internal latent heat.

3. The latent heat of volume, or the external work done by the steam in making room for itself against the pressure of the superincumbent atmosphere.

The sum of the last two taken together is called the latent heat of steam. The heat required to generate 1 lb. of steam at 212° from water at 32° is:

Sensible heat to raise water from 32° to 212° =		180.9°
Latent heat: (1) of the formation of steam at 212°	=894.0°	
(2) of expansion against atmospheric pressure, 2116.4 lbs. per sq. ft. × 26.36 cu. ft. = 55786 ft. lbs. ÷ 778	= 71.7°	965.7°
Total above 32°		1146.6°

Q. 77. (1896-7.) What is the absolute zero of temperature, and how found?

Ans. 77. The absolute zero of temperature is a condition in which there is supposed to be no heat whatever, and is taken to be 461° below zero of the Fahrenheit scale. According to the law of Gay Lussac, a perfect gas will decrease 1/461 part of its volume at 32° F. for each degree of heat abstracted.

Thus, if from a given volume of gas at zero 1° of heat be taken, the resulting volume will be 460/461 of the former volume, and if 2° be taken away the resulting volume will be 459/461 of the original, and so on down until the temperature has reached 461° below zero, when, in theory, gas will have no volume and no heat. It is not possible to prove to a certainty the truth of this law, because we have no means of producing so low a temperature nor any means of measuring the quantity of heat.

Experiments have been carried so far in this line as to remove all reasonable doubt of the practical application of the law. Regnault's and Tate's experiments place the absolute zero at 458.71° F. below zero.

Q. 78. (1896-7.) What is meant by the British Thermal unit?

Ans. 78. The British unit of heat, or the British thermal unit, or B.T.U., is that quantity of heat which is required to raise the temperature of 1 lb. of pure water 1° F. at or near 39.1° F., the temperature of its maximum density. Peabody's definition: The heat required to raise 1 lb. water from 62° to 63° F. is not generally accepted. The mechanical equivalent of heat, or of a unit of heat, is 778 foot-lbs. of energy.

Q. 79. (1896-7.) What is meant by specific heat?

Ans. 79. Specific heat is a term used to define thermal capacity, and is usually a fractional number or coefficient which expresses the relative heat storing capacities of different substances as compared with some substance taken as a basis and which has an assigned value of 1.

The unit or basis taken for specific heat tables in which solids and liquids figure is usually water and the quantities of heat taken up by equal weights of various substances, for equal increase in temperature, are compared with a like weight of water.

Illustration: Thus, if the base of the table is water, with an assigned value of 1, we find the specific heat of wrought iron is .1138, this fraction representing the relative quantity of heat which 1 lb. of wrought iron will absorb or give out, as compared with the same weight of water, the temperatures of both being raised or lowered equally.

Q. 82. (1896-7.) Can steam be liquefied by pressure without the radiation of heat?

Ans. 82. No. As no heat is allowed to escape the steam is compressed adiabatically, work done on the steam by the act of compressing it, which represents so much added heat, enabling it to exist at a higher pressure. The more it is compressed the greater will be the increase of temperature. Not only is the heat sufficient to maintain the steam in its gaseous form, but if there is water in the cylinder at same temperature the heat generated by the compression is sufficient to turn all or part of it into steam.

Q. 83. (1896-7.) Is oil or grease the better general lubricant for bearings?

Ans. 83. The elements which determine the value of a lubricant are the cost due to consumption of the lubricant, the expense for fuel used in overcoming frictional resistance during use of lubricant and the cost of renewing worn journals and boxes.

The economy of one oil over another, so far as durability is concerned, is simply proportional to the rate at which it can insinuate itself into and flow out of the bearing. This ability is governed by the viscosity of the lubricant and the amount of foreign matter in it.

Where the lubricating film of oil or other substance is thick and large amounts will pass through a box or bearing, the greater the viscosity the less will be the flow of waste. Other things being equal, an oil with imperfect fluidity will be the cheapest. When the feed of an oil is restricted, as in case of crank pins, and yet the flow must be constant and steady at normal temperature, it is hardly practicable to feed greases or heavy oils.

In a general way, for heavy pressure and slow speed, grease or heavy oil is best. For light pressure or high speeds oil is best. For ordinary factory shafting, grease is clean, convenient and cheap.

Q. 85. (1896-7.) What is meant by the critical temperature?

Ans. 85. There appears to exist for each and every gas a temperature above which it cannot be liquefied at any pressure. This is called

the critical temperature—all gases or vapors can be liquefied below that temperature if sufficient pressure is used.

Q. 97. (1896-7.) How large a steam radiator needed to heat an office 15 ft. by 20 ft., with a 12 ft. ceiling?

Ans. 97. The size of steam radiator to heat an office depends upon location, surroundings, exposure, cubical contents of the office, number of doors and windows, external temperature, style of heater, whether direct or indirect, etc., etc.

Assuming that the office is favorably situated as one of a suite in a well constructed building with but one out-door wall and window and located in the northern temperate zone of the U.S.A., then 48 sq. ft. of radiation will suffice to warm the room to 70° in zero weather. To find it, proceed as follows: Get cubical contents of room, then $15' \times 20' \times 12' = 3{,}600$ cu. ft. space; divide by factor 75, gives 48 sq. ft. for an answer, calling for 144 lineal feet of 1″ pipe, or 125 lineal feet of 1¼″ pipe, or an ordinary 12-loop sectional radiator containing 4 ft. to the loop. Experience and conditions determine the factor to be used, which varies from 40 or 50 to 200 or 250, to meet the conditions mentioned in introduction of this answer.

Q. 22. (1897-8.) What is a calorimeter, how constructed, and for what purpose used?

Ans. 22. The calorimeter is, as its name implies, an apparatus for measuring heat. In stationary engineering there are two kinds of calorimeters, one for the purpose of ascertaining the amount of moisture in steam, the other for ascertaining the heat value of coal.

A type of the first kind is the barrel calorimeter. This consists essentially of a barrel of water with a steam pipe leading into it. The steam to be tested is allowed to run into and be condensed in the water. A comparison of the increase in weight and in temperature of the water will show the percentage of water carried in with the steam.

The second form consists essentially of one vessel placed within another. The outer vessel contains water. A small portion of the coal to be tested is placed in the inner vessel, which is supplied with oxygen gas. The coal is rapidly and completely burned in this gas, and the amount of heat generated by its combustion is measured by the rise in temperature of the water.

Q. 26. (1897-8.) What is meant by the "viscosity" of oil? How can the relative viscosities of two specimens be conveniently determined and to what extent is it a criterion of the value of the oil?

Ans. 26. Viscosity is the friction of the particles upon each other. The relative viscosity of two specimens of oil may be approximately determined by filling a small vessel with the oils, one after the other, allowing them to run out through small orifices and noting the time required to discharge equal quantities. The specimen taking the longer time to run out is proportionately more viscous.

The viscosity is often taken as an index of the value of the oil for heavy work.

Q. 27. (1897-8.) What is the rule for finding the number of foot-pounds of work necessary to change the velocity of a body of known weight from one value to another?

Ans. 27. Subtract the square of the lesser velocity from the square

of the greater velocity and multiply the remainder by the weight. Divide that product by 64.4 and the result will be the required number of foot-pounds. Velocities are taken in feet per second, and weight in pounds:

This is expressed algebraically as follows:

$$E = \frac{W.(V^2 - V_1^2)}{64.4}$$

in which W = weight in pounds, V_1 the less and V the greater velocity in feet per second, E = energy in foot pounds (work).

Q. 31. (1897-8.) What is the rule for obtaining the centrifugal force of a given weight, moving in a circle of a given radius, with a given velocity?

Ans. 31. The formula for centrifugal force is

$$\frac{WV^2}{32.2\,R}$$

in which R is expressed in feet and fractions thereof.

Multiply the weight by the square of the velocity and divide the product by 32.2 times the radius. The radius is to be taken in feet, velocities in feet-per-second, and weight in pounds.

Q. 32. (1897-8.) For the engine of Q. 28 draw a diagram to scale, by help of the rule of Ans. 31, such that horizontal distances shall represent piston-positions, and vertical distances the force exerted by the inertia of the piston, piston-rod, and cross-head, at each piston-position.

Ans. 32. Lay off as before a horizontal line a, b, Fig. 3, to represent

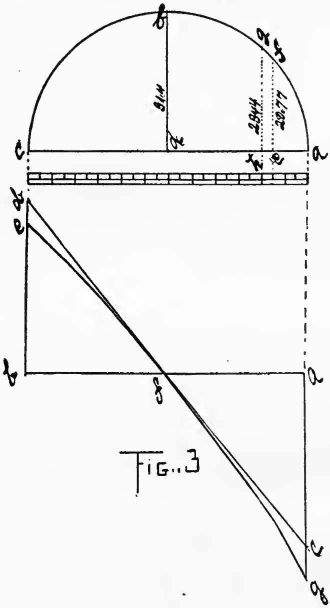


FIG. 3

the stroke. Imagine that the total weight of the parts is upon the crank-pin and calculate what the centrifugal force would be. Lay off a line a, c, proportional to this force, vertically downward from the end of the line a, b, which represents the commencement of the stroke. Lay off a line b, d, vertically upward from the other end of the line a, b, and connect the points c, and d, by a straight line. Then will points in the line a, b, represent piston positions and the vertical distances from said points to the line c, d, will represent the force of inertia at the corresponding points in the stroke. Distances downward from the line a, b, represent pulls on the connecting rod; distances upward, pressures upon the same. The above diagram neglects the effect of the change in angularity of the connecting rod. This may easily be taken account of, however. If to the line a, c, you add the proportion of its length equal to the ratio of the crank, to the connecting rod, in this case 1/6, and subtract the same amount from the line a, d, and then draw the regular curve e, f, g, through the points thus found and through the center of the line a, b. Then vertical distances to the line e, f, g, will represent, to the scale chosen, the force of inertia at every point of the stroke.

The application of the forces of inertia to cause the proper action of an engine was first worked by a practical man having little or no book learning. The theory and method of measuring and estimating such forces has since been so simplified that a child may understand it, if he will try.

Q. 33. (1897-8.) What is the principle of the parallelogram of forces?

Ans. 33. If two forces are represented in intensity and direction by two lines, the resultant of said forces will be represented in intensity and direction by the diagonal of a parallelogram of which the lines representing the first two forces are the sides. If the resultant of two forces is represented by a line, the forces themselves will be represented by the adjacent sides of a parallelogram formed with the first mentioned line as a diagonal.

The formula for the stored work in a moving body, which is called the fundamental formula of mechanics, and the formula for obtaining the centrifugal force of a body should be remembered. The similarity between these two formulæ will help to fix them in the memory.

The formula for stored force is

$$\frac{WV^2}{64.4} = \text{foot lbs.}$$

The formula for centrifugal force is:

$$\frac{WV^2}{32.2\,R} = \text{lbs. of centrifugal force.}$$

Q. 40. (1897-8.) What is meant by the flashing point of an oil? How may the flashing point of a sample be determined?

Ans. 40. The flashing point is that temperature of the oil at which it gives off vapor at a sufficiently high rate to form an inflammable mixture with the air above it.

The point may be determined by gradually raising the temperature of the oil and occasionally passing a flame above it. The temperature at which the vapor takes fire is the flashing point.

Q. 44. (1897-8.) How is the safe torsional strength of a round shaft of machine steel calculated?

Ans. 44. The force multiplied by the lever arm at which it acts (the moment) is equal to 12,000 times the cube of the diameter of the

shaft. The units are in inches and pounds. Let $P =$ the force in pounds.

$A =$ the length of the lever arm in inches.

$d =$ diameter of the shaft in inches and fractions thereof.

This would be expressed arithmetically as:

$$P = A\ 12000 \times d \times d \times d.$$

Algebraically:

$$PA = 12000d^3.$$

For ordinary working, about one-eighth of this value would be taken:

$$PA = 1500d^3.$$

One will find a variety of answers to Q. 44, which may weaken his faith in this kind of calculation. Experience in the use of the formula will certainly restore his confidence. The varieties of values given are probably owing to a difference of opinion as to what is safe. Sometimes one only wants a part to last a comparatively short time, and sometimes it does not matter much whether a part breaks or not. In these cases one might wish to allow a greater strain than in other cases. We have used machine parts subject to a strain 75% greater than the largest given. These have stretched, bent, or broken, more or less, sooner or later, however.

The modern understanding of the nature of metals is that they will always give way sooner or later under repeated strains. When a metal part will break is merely a question of time. The further the strains are below the elastic limit the longer the part will last. It is for this reason that a considerable factor of safety should be taken in most cases. We believe the best statement of the theory, and digest of experience, relating to the so-called "Fatigue of Metals" is to be found in Prof. Weyrauch's book translated by Prof. A. J. DuBois. We think it is published by Wiley.

Q. 45. (1897-8.) If the rule is taken that a shaft must not twist more than one degree in 10 ft., what is the allowable moment, or torque, for a machine steel shaft 1½" in diameter?

Ans. 45. For soft steel and wrought iron, the following rule may be taken:

The allowable moment is equal to 160 times the fourth power of the diameter of the shaft. Inches and pounds are used.

This is expressed arithmetically as:

$$160 \times d \times d \times d \times d.$$

Algebraically as:

$$160d^4 = M.$$

With a 1½" shaft, the allowable moment under the given conditions is:

$160 \times 1.5 \times 1.5 \times 1.5 \times 1.5 = 160 \times (1.5)^4 = 160 \times (5.0625) = 810$ statical inch-pounds.

The formula given will be found to correspond very closely with practice. If tempered spring-steel is used the constant 185 should be used instead of 160.

If one wishes to know how many degrees a given force upon a lever arm of a given length will spring a shaft 10 ft. long of a given diameter he can calculate it by the following formula:

$$D = \frac{M}{160d^4}.$$

in which D is the angle in degrees, M is the moment (i. e., the force multiplied by the lever arm), 160 a constant for wrought iron and soft steel, and d the diameter of the shaft in inches. For other lengths of shaft the angle will be proportional to the length.

Q. 46. (1897-8.) If it is assumed that the extension of a rod is always proportional to the load, what load would extend a machine steel rod of one square inch cross-section its own length? What is this number called?

Ans. 46. About 30,000,000 lbs. This number is called the coefficient or modulus of elasticity.

The utility of the coefficient of elasticity referred to is believed to be that it obviates the necessity of taking into account the length of the particular rod. This is illustrated in Ans. 47. This coefficient is quite constant for different specimens of steel, but varies somewhat, especially between hard and soft metal. The First German association, No. 15, of Ohio, find it to be 29,200,000; your committee has found it greater than 30,000,000 in tempered steel.

Q. 47. (1897-8.) If a machine steel rod is immovably attached at its ends when it is at a temperature of 100° what will be the strain upon it when it has cooled down to 50°?

Ans. 47. If 1° fall in temperature contracts a rod .0000065 of its length, a fall of 50° would contract it .000325 of its length. If the rod was prevented from contracting it would exert a force equal to that which would extend the rod that distance. That is $30{,}000{,}000 \times .000325 = 9750$ lbs. per square inch.

Q. 55. (1897-8.) A round wrought iron rod 3 ft. long and ¾″ diam. is rigidly fastened at one end and extends horizontally, what weight will it support at the outer end?

(b) What weight can be put on its outer end for safe working under ordinary conditions of practice?

Ans. 55. (a) The greatest weight the rod could be expected to hold may be found by the following:—

Rule:—Multiply the cube of the diameter of the rod (in inches and fractions thereof) by the constant number 4900 and divide by the length of the rod in inches.

The cube of .75 is .422; $.422 \times 4900 = 2068$, and this divided by 36, the length of the rod, is 57.8, which is the largest weight in pounds that the rod could be expected to hold at its end.

(b) The largest weight the rod could be expected to hold without being permanently bent may be found by the following:—

Rule:—Multiply the cube of the diameter of the rod by 1960 and divide by the length of the rod.

This would give about 23 lbs. as the weight that would bend the rod to its limit of elasticity. About half this, or say 12 lbs., would be taken in practice for ordinary constructions.

Q. 56. (1897-8.) (a) A wrought iron rod of rectangular cross-section on 1.5 "vertically and ¾″ broad, is rigidly fixed at one end so as to extend horizontally, what weight will it support 4.5 ft. from the fixed end? (b) What weight will it safely carry under ordinary working conditions?

Ans. 56. (a) The rule for obtaining the greatest weight the rod could be expected to hold may be taken as:—Multiply the breadth by the square of the height and this product by the constant number 14000, and then divide this last product by the length of the rod in inches.

Thus $.75 \times 1.5 \times 1.5 \times 8311 \div 54 = 260$ lbs., as the greatest weight the rod could be expected to sustain.

(b) The weight that will strain the rod to its limit of elasticity may be found by the following:—

Rule:—Multiply the breadth of the rod by the square of its height and this product by 3350 and divide by the length of the rod in inches. In this case the result would be 104 lbs. as the weight that would stretch

the rod to the limit of elasticity. About half this last result is taken in practice. This would give 52 lbs.

In rods subjected to a bending force (Ans. 55-56) the upper and lower fibers may be overstrained while the rest of the rod is within the allowable stress. In special experiments for the purpose of this article the round rods bent and stayed bent when subjected to a force a little greater than given by the first rule. If the force had been continued they would have broken. Probably the rods would have gradually bent in use with a strain much greater than given by the second rule.

Q. 59. (1897-8.) What is the relative strength of wrought and cast iron—

(a) When subjected to a crushing force?

(b) When subjected to a tensile force?

Ans. 59. (a) Wrought iron is from 1/2 to 1/3 as strong as cast iron when subjected to a compressive strain.

(b) Wrought iron is from 2 to 3 times as strong as cast iron when subjected to a strain in tension.

Q. 60. (1897-8.) There is a wrought iron bolt ¾″ diam. having ten U. S. standard threads to the inch cut in it. What is its breaking strength?

Ans. 60. About 12 000 lbs.

Question 1. (1898-9.) Everything in the universe occupying space is considered under the general head of Matter. Explain in this connection the difference or distinction made between Atoms, Molecules and Bodies; also define the relation of these terms to what are known as elementary and compound substances.

Ans. 1. A substance which by no process can be decomposed or separated into anything different from itself is classed in chemistry as an element; in a scientific sense an atom is the final or indivisible particle of such a substance.

Compound substances are always composed of two or more different "elementary" atoms; thus one atom of oxygen, when combined with two atoms of hydrogen, forms a single molecule of water, hence the molecule is the smallest particle of a compound substance that can exist.

A "mass" or tangible particle of any substance may be referred to as a "body."

It should be understood that atoms and molecules are so small as to be far beyond definite analysis. Some idea of the minuteness of matter can be conceived by noting the large area of water over which a single drop of oil will distribute itself. In so thin a film as this the molecules of oil are far from being isolated, and, incredible as the explanation may seem, scientists agree that all "matter" is constituted or "built up" from particles of infinite size.

In detail, the foregoing subject embraces the atomic theory, which is universally accepted as a satisfactory explanation of all chemical phenomena. Unless mentally well equipped with a good conception of this theory no engineer can hope to understand the most important facts relating to furnace combustion or other chemical and physical changes over which he assumes guardianship.

Q. 2. (1898-9.) Pure iron is known as one of the elementary metals—why cannot steel be so considered?

Ans. 2. Iron of commerce is not a strictly pure metal, but when free from impurities it is one of the so-called "elements." Properly combined with certain definite proportions of carbon the internal structure of iron assumes the characteristics of steel, and therefore, being

the result of a chemical combination, steel cannot be considered an elementary substance.

Q. 3. (1898-9.) It is said that elementary substances may lose their identity, but can never be destroyed:—explain why this must be true and define the difference between physical and chemical changes in substances; also give a few familiar examples, confining the subject to the steam boiler.

Ans. 3. Physical and chemical changes are treated separately in science. Natural philosophy or "physics" concerns phenomena whereby substances acted upon do not lose identity of composition. Hardening, annealing, breaking or magnetizing a piece of steel are simply physical changes—no atoms are added, none are lost. The properties of a substance may vary as the result of a physical change; for instance, by a continued abstraction of heat water is converted from the fluid to the solid state. In this, and also when water is converted into gaseous steam, the chemical "make up" (barring all foreign matter, of course) remains the same.

The melting of one pound of ice will yield a pound of water, as will also the condensation of a pound of steam.

The physical change in water, from the fluid to a gaseous state, as carried out in the steam boilers, is due to a chemical process; i. e., furnace combustion. Carbon, the predominating element in coal, under the influence of an elevated temperature, is released, atom by atom, and when combustion is perfect each atom "pairs off" with two atoms of oxygen, the latter being derived from the air which is fed to the furnace. Nitrogen is set free, and the oxygen, together with the carbon, now forms a product called carbonic acid gas. "Burning," therefore, is a chemical action and a source of heat; the fuel—minus ash and clinkers—disappears, and apparently "matter" has been destroyed. True, the carbon and oxygen in their new molecular relation, together with the nitrogen from which the latter gas has parted company, have flitted into space, but by no means is either lost; they have gone, but only to seek new combinations, and in time they find the affinities which Nature has decreed.

To plant life, under the influence of sunlight, devolves the office of again separating the carbon from the oxygen, and to this source can be traced our present stores of fuel. Fuel can be burned as we will, but each atom thereof represents a part of a universe in which things are muchly shifted about, but nothing is ever completely annihilated.

Q. 4. (1898-9.) What is vacuum? Why is it impossible to maintain such over or in connection with water?

Ans. 4. Space devoid of matter. From an engineer's standpoint, a vacuum refers to some chamber partially relieved of atmospheric pressure.

A perfect vacuum, though realized, could not be maintained over or in connection with water, because liquids give off vapor, which rapidly refills the empty space; at a temperature of 60° Fahr. the absolute pressure due to the vapor of water is a quarter of a pound per square inch. A mercury gage would give an indication of 29.4 inches, which represents the best permanent "vacuum" obtainable at that temperature.

At 100° Fahr. the same gage would read 28 inches, and so up the scale for increased temperature until at 212°, the boiling point, the vapor balances the normal pressure of the atmosphere.

Q. 5. (1898-9.) Extension or volume expresses dimension and no body can be conceived that does not possess length, breadth and thick-

ness; neither can two bodies occupy the same space at the same time, hence—matter is impenetrable.

Extension and Impenetrability are regarded as the essential properties of matter; in addition to this certain general properties are accredited. Name nine other general properties.

Ans. 5. No particle or body of matter can be conceived that does not possess length, breadth and thickness; neither can two bodies occupy the same space at the same time.

The essential properties of all matter, i. e., extension and impenetrability, are defined by the foregoing statement. Nine other general properties accredited to matter are as follows:

Weight: Due to the force of gravitation.

Mobility: By virtue of which the position of bodies may be changed by the application of suitable force.

Inertia: Which defines the persistency of bodies to retain their state, be it motion or rest.

Divisibility: All matter can be divided into distinctly different parts. There are practical limitations to dividing a substance; theoretically the final limit is assumed to be the atom or molecule, as already explained.

Porosity: The ultimate particles of a substance, though apparently dense, are supposed to be suspended in space, and therefore not in actual contact. All matter is more or less porous.

Compressibility: Which means the volume of any body may be diminished; this is a sequence to "porosity."

Expansibility: The converse of compressibility, i. e., substances will vary in volume or size at different temperatures.

Indestructibility: Matter may be caused to vary in form, but, as already explained, its elementary existence can never be destroyed.

Elasticity: Within certain limits, and varying in different substances, bodies tend to recover their original shape when relieved from the strain due to an applied force.

Q. 6. (1898-9.) Why are hardness or elasticity considered as specific properties of matter?

Ans. 6. Hardness: When used to define the property of a substance, like stone; or elasticity, when used to characterize the peculiar tendencies of rubber, are regarded as expressive of specific properties; for not all bodies are hard or elastic in the sense here implied.

Q. 7. (1898-9.) Affinity, Cohesion and Gravity are known as natural forces. Explain by familiar examples some of the effects attributed to each.

Ans. 7. Affinity, cohesion and gravity are the three great forces of Nature.

Affinity is the strongest of the forces, but acts only through infinitesimal distances—that is to say, it is the power that binds together the atoms which constitute the molecule of a compound substance. Water exists because the atoms of hydrogen and oxygen are held together by "affinity." Affinity is considered an atomic force.

Cohesion is weaker than affinity—acts through greater but still insensible distances only. It binds into a mass molecules of similar nature and is the power by which a homogeneous body retains its form, tenacity, etc.

Cohesion is considered a molecular force.

Gravity is the weakest of these three natural forces, but acts through all known distances. It tends to bind "bodies" together, as is manifest by the attraction which is known to be mutual between all bodies in the universe.

Gravity is known as a molecular force.

Q. 8. (1898-9.) Give another and more familiar name for the force known as "adhesion"; give the cause for its action and examples of what would happen if it ceased to exist.

Ans. 8. Adhesion is classed as a force causing molecules of different kinds of matter to "cling" together. Chalk clings to the blackboard; dust of any kind clings to every substance; bricks adhere to mortar, etc. Friction is a form of adhesion, and it is a mistake to assume that the resistances due to this cause are without compensating advantages. The stability of the major portion of everything erected by man depends on friction, and "pell mell" destruction would follow in the wake of a frictionless era.

Q. 9. (1898-9.) What are the three states of matter? Name the force which causes a change of state.

Ans. 9. Matter exists in three different states, which are distinguished as the "solid," "liquid" and the "gaseous" state. The state of matter varies with the force of "cohesion," which is strongest in solids, weakest in liquids, and totally lacking in gases. The intensity of cohesion is influenced by temperature.

Q. 10. (1898-9.) "Force"—define this term in the broad sense in which it is used in science.

Ans. 10. "Force," in a broad sense, is "that" which causes any sort of change in matter, or such as may vary the form of substance or alter its condition or position in space.

Q. 11. (1898-9.) Mechanics is a branch of science that treats of the effects of force upon matter. Nothing is known of force except through matter; the two may be regarded as inseparable. Motion is one of the effects of force; name another.

Ans. 11. Mechanically considered, "force" is the cause of motion, or is "that" which tends to produce motion, either retarding or totally preventing the movement of bodies to which it is imparted.

The effect of force, not manifest as motion, is "strain."

Q. 12. (1898-9.) What causes "strain" and how is it measured?

Ans. 12. Strain is due to resistance or the reaction of opposed forces. It is measured in units of weight.

Q. 13. (1898-9.) What is motion?

Ans. 13. "Motion" signifies change of position. A body moving or changing its place, with regard to some point that is fixed, is said to have an "absolute motion." Relative motion refers to the movement of a body when taken with reference to another moving point.

Q. 14. (1898-9.) What is "velocity" and how is it usually expressed?

Ans. 14. Velocity, usually expressed in feet per second, or some convenient multiples of either of these units, is indicative of the "rate of motion," i. e., time and space.

INTRODUCTION TO QUESTIONS 15 to 30 (1898-9).

The foregoing questions deal primarily with the well established theories concerning the constitution of matter and should have served the purpose for which these questions are intended, i. e., to give the uninformed a partial insight as to how scientists view nature in the

abstract. A better comprehension of the Atomic Theory, the salient points of which are referred to, is another of the objects sought; and in no instance can the aims of the committee fall short of the mark, where associations or individual members have taken up the work in the manner and spirit prescribed.

A thorough understanding of nature's laws, such as may be obtained by an intelligent interpretation of fundamental points, is deemed essential and it is hoped that none seeking enlightenment consider themselves so well equipped in a "practical way" as to be exempt in this particular.

In thus advocating the cause of theoretical knowledge and insisting that the progressive engineer or mechanic cannot afford to be blind to the teachings of science, we may say further, that the most important and useful of these facts are not at all abstruse and can readily be acquired by energetic believers in the forcible principle of removing an obstacle, in preference to being continually hampered by it. The second paper of the Review is offered, therefore, as additional aid in "smoothing the roadway." The Educational Committee feels confident that its efforts in this direction are not misdirected.

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In pointing out material which should be mastered, to insure advancement, we cannot overlook the importance of mathematics as a factor concerned in nearly every proposition of a mechanical nature. To beginners in this most needful branch of learning we would say that, in this as in every other branch of science, certain fundamental principles must be absorbed to facilitate progress. Ordinary arithmetic is the stepping stone to such higher "planes" as algebra, etc.; for the present, however, we would advise a sojourn on the lower level, each individual to remain there until such time that he can "reason" himself to a more exalted position in mathematics.

A good practical knowledge of arithmetic means more than an ability to add and subtract, multiply and divide; more especially if these operations are carried out in the mechanical manner, which is not at all uncommon. The impracticability of reaching this subject by any other method has prompted the measure we provide; the article which follows is intended for all who choose to inquire into their mathematical standing; the view being taken from a strictly elementary standpoint. The matter is pertinent at this time and, while directed at the rudiments of arithmetic, its broader aim is to inculcate the need of constant reasoning in all that pertains to the attainment of an education.

MATHEMATICS.

Mathematics is the science of quantity and embraces Arithmetic, Algebra, Geometry, etc.

Arithmetic is more particularly the science of numbers and to a partial consideration of the rudiments of this subject the following is directed:

The first proposition engaging the attention of a beginner in arithmetic is usually stated thus: "A unit is one," a single thing. An engine, for instance, is built up of distinct pieces, but considered collectively, we refer to it as a single thing. "One" as a unit, therefore, may represent either a definite quantity or an aggregate of quantities.

Quantity is anything which can be increased or diminished. Magnitude is quantity, considered in an individual form. Multitude is quantity, when made up of individual or distinct parts.

Number is a term covering broadly all answers to the question: How many? When one or more things are "counted," the result is expressed by a number which denotes the sum total of units under consideration.

Numbers, applied to any particular thing, as one engine, two boilers, etc., are defined as "concrete numbers"; all numbers not associated with something tangible, are considered "abstract."

Notation is the shorthand method of expressing numbers by characters called "figures." Numeration is the art of reading numbers so written.

The figures commonly used are 0-1-2-3-4-5-6-7-8-9; combinations of these serve to express any number the mind can conceive.

The figure 9, appearing alone, stands for "nine"—not because the symbol is especially adapted to represent this number, but because it is part of a "system," which assigns a universally recognized value.

When appearing alone 9 stands for the greatest possible number of units that can be given expression, by any single figure; counting from one to nine exhausts the significant figures, and at this point the elasticity of the system becomes manifest.

Further progress in notation is made by assuming the next higher number as the initial unit of a higher order, i. e., one unit of the new order being the equivalent of ten single things as originally conceived. To express this number we again revert to the figure 1, using in connection therewith the auxiliary digit 0, writing 10, to represent ten, and considering same as a single unit of the second order or place. The need of the character 0, referred to as an auxiliary and usually called naught or cipher is self evident; it has no assigned value, but its position at the right of any figure increases the numerical value thereof tenfold.

At 99 we have nine units of the order of tens and nine simple units, the sum being equivalent to ninety-nine, the largest number capable of expression with two figures. It is plain, however, that the process of building up additional orders can be repeated and the system extended indefinitely.

Numbers written with more than three figures, are for convenience divided into groups of three places each, which are known as periods. This grouping of the orders into sections of three is indicated by dots, placed to precede the first figure of each period.

The first period consists of Units, Tens, Hundreds, and is called Unit Period; thus the number 583 stands for five hundred and eighty-three units.

The second period is also taken to consist of Units, Tens and Hundreds, but each unit here has a value one thousand times greater than assigned the figures in the first period; hence 583,000 is read five hundred and eighty-three thousand.

Additional periods are successively Millions, Billions, Trillions and so on upward into a maze of figures that seldom, if ever, need invade the engineer's mind.

The foregoing epitome of the Arabic System of Notation embraces points more dormant than new; it is, however, the "essence" of arithmetic and, as such, the several definitions must not suffer rusty repose in our intellects.

Four fundamental operations in arithmetical computations are Addition, Subtraction, Multiplication and Division, represented and indicated respectively by the familiar signs $+$, $-$, $\times$, $\div$. The several processes are based upon and carry out the principles set forth in the ground work of Arabic notation and when a correct idea of the system of "unit values" is once firmly rooted in, and thoroughly comprehended, a mathematical stride of no mean importance has been accomplished.

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To profit by the experience of others, and to arrive at conclusions for himself, also to lessen the labor involved in many calculations, the engineer must learn to read abbreviated mathematical propositions and should understand the "short cut" methods which facilitates the operations indicated. This does not necessarily imply a profound knowledge of Algebra, as the operations indicated in some of the most useful engineering formulae are readily solved by arithmetical computation. The fact that a person can add, subtract, multiply and divide is not enough for the purpose; there is much more than this between the

covers of a common school arithmetic which may be absorbed and used with profit and effect.

Mathematics is essentially a science of reasoning and the better the cultivation of the reasoning power the less burdensome becomes the mathematical labor attached to the work. To this end, therefore, a plea is made for a recognition of the true value and importance of the principles as set forth in any ordinary arithmetical text book. It may seem tiresome, or may be even frowned upon as "folly" by some, to again take up studies of the kind here recommended. Many of course are far past this stage, but none have traveled a better or easier route. C. H. F.

Note.—Anything assumed as One may be taken as a Unit. Some particular thing, or rule, established to fix a permanent value, becomes a "standard"; and as such it serves as the accepted measure for the purpose it is designed for. The absolute need of unchangeable "standards," by which values, etc., may be measured and compared, is self-evident. Every civilized nation defines its units of measurement with accuracy and upholds and enforces them by legal enactments.

This paper is largely given to the consideration of the units embraced on the engineer's "yard stick," and those not already conversant with the subject should cultivate that intimacy which its importance demands.

Q. 15. (1898-9.) First Law—Every body continues in a state of rest, or of uniform motion in a straight line, unless acted upon by some external force.

Second Law—Motion, or a change of motion, is proportional to the force impressed and is in the direction of the line in which that force acts.

Third Law—Action and re-action are always equal and are in opposite directions.

Who was the first to give expression to the foregoing?

Ans. 15. The three "Laws of Motion" are accredited to Sir Isaac Newton.

Q. 16. (1898-9.) Weight is due to the force of gravitation, hence every operation of "weighing" is a measurement of that mutual attraction, which is inherent to every particle of matter in the universe.

Give the units of weight commonly used in engineering.

Ans. 16. Avoirdupois, or Commercial Weight, is the common standard of the United States; the principal unit is the "pound," but great weights are more conveniently expressed in tons, the latter being a multiple of the original unit. The legal definition of the ton is 2,240 pounds; the short ton of 2,000 pounds is customary in many branches of trade.

The avoirdupois ounce is 1/16 of a pound; in engineering calculations it is preferable to express such fractions in decimals of a pound.

"The standard avoirdupois pound is equivalent to the weight of 27.7015 cubic inches of distilled water, weighed in air, at 39.83° Fahr., barometer at 30 inches."—Haswell.

The French, or Metric, system is also a legal standard in this country.

Q. 17. (1898-9.) A line is length without breadth or thickness.

A straight line is the shortest distance between two points.

How is the measurement of length ordinarily expressed and upon what is the unit based?

Ans. 17. The foot, and its subdivision, the inch, are the units generally used for expressing "Long Measure."

The United States and British standards are the same, and the fundamental unit is the yard, which is said to have been based originally

on the length of a pendulum vibrating seconds at the level of the sea, in the latitude of London, in a vacuum, with Fahrenheit thermometer at 62°. The length of such a pendulum is supposed to be divided into 39.1393 equal parts, called inches, and 36 of these inches were adapted as the standard yard.

Q. 18. (1898-9.) As a matter of convenience many of the standard units of measurement are either subdivided or used in multiple; thus "Time" is noted in seconds, minutes, hours, etc. It would be awkward to refer to 600 seconds of time, but six seconds is a more ready expression than six-sixtieths of a minute and so on.

Frequently certain units are combined and thus form a new measure.

Assuming the minute as the unit of time, what important other unit is evolved when expressed in connection with those representing weight and distance?

Ans. 18. Using the minute as expressive of the "time"; the pound representing "weight," and the foot indicating the space or distance traversed, gives us the "foot-pound," or the unit of work. Time, weight and space are inseparably linked in the measurement of power, and the elements embraced in this most important unit should be understood in a way inspiring a full confidence as to what they really portend. Hazy views on this point will impede progress.

Q. 19. (1898-9.) Explain the relation between "foot-pounds" and "horse-power."

Ans. 19. 33,000 foot-pounds are the equivalent of one horse-power; both are units for the measurement of work or power—the relation between them being similar to that of the pound and the ton; that is. one being a multiple of the other, both expressing the same thing.

Q. 20. (1898-9.) Area is a term used to express the superficial contents of any figure. Give the units usually used in this connection and define a "plane" surface.

Ans. 20. Surface or area is expressed in square inches or square feet, as best befits the case. By a "plane figure" is meant any flat surface enclosed by real or imaginary lines which form the outlines or boundary thereof. Such a figure is assumed to have length and breadth, without thickness, and its surface is computed in squares corresponding to the units used in measuring its lineal dimensions.

Q. 21. (1898-9.) Length, breadth and thickness are essential to volume. How would you express the volume or cubical contents of a solid?

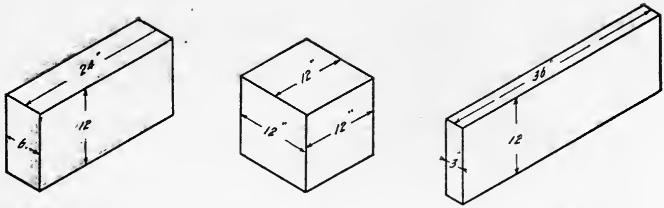
Ans. 21. As indicated in the question, three dimensions are essential to volume—that is, we measure length, breadth and thickness and express "cubical contents" in cubic inches, cubic feet, and so on, as the case may require. Awkward and ridiculous blunders are a frequent result from the careless confounding of the expressions noted in this and the preceding question.

Q. 22. (1898-9.) Give the name of a unit commonly used in measuring fluids and state upon what it is based.

Ans. 22. The United States standard gallon, containing 231 cubic inches, is a common measure for liquids.

Q. 23. (1898-9.) Sketch diagram representing blocks, measuring in inches, 12″ × 12″ × 12″; 24″ × 12″ × 6″; 36″ × 12 3 ; calculate cubical contents of each in feet, and surface in square feet. Demonstrate thoroughly the difference between solid and surface measurement.

Ans. 23. See cuts.



24" × 12" × 6" Volume one cubic ft. Surface 7 square ft.

12" × 12" × 12" Volume one cubic ft. Surface 6 square ft.

36" × 12" × 3" Volume .75 cubic ft Surface 8 square ft.

ANSWER NO. 23.

Q. 24. (1898-9.). Geometrically considered the circumference of a circle is a curved line, all points of which are equally distant from a certain point within, called the center.

The unit ior measuring angles is derived from the circumference of a circle.

Give the recognized name of an angle measuring 89 degrees 59 minutes and 60 seconds; explain briefly how this measurement is applied and the signs used to abbreviate the units mentioned.

Ans. 24. Circular measurement assumes the periphery of the circle divided into 360 equal parts, each of the spaces being known as a "degree." The degree is divided into 60 equal parts, called "minutes," and a further subdivision of the minute into 60 parts gives seconds. The signs or abbreviations used are thus: 89°, is read, eighty-nine degrees; 59′, indicates fifty-nine minutes, and 60″, refers to sixty seconds. An angie measuring 89°, 59′, 60″ is the equivalent of 90 degrees, and is—

$$\frac{360}{90} = 4$$

therefore the fourth part of a circle. In more ordinary language, such an angle is a square, and geometrically it is defined as a "right angle."

Q. 25. (1898-9.) Temperature is also expressed in "degrees," but it is evident that heat and cold do not enter into a geometrical proposition.

Explain the mercurial thermometer and Fahrenheit's scale.

Ans. 25. The principle involved in the ordinary mercurial thermometer hardly requires special mention; interest centers rather to the scale or graduation by which the expansion and contraction of the mercury is measured and by which the instrument is read.

"Fahrenheit" is the common U. S. standard in engineering practice, and this scale, which takes the name of its originator, marks the boiling point of water by 212° and the freezing point by 32°.

Zero, or 0°, was fixed at the temperature acquired by a mixture of ice and salt. Thermometric scales are entirely arbitrary, but once established and recognized, this fact in no way detracts from their general usefulness.

Q. 26. (1898-9.) Explain briefly the principle embodied in a barometer; state how this instrument is read and what the reading indicates.

Ans. 26. The barometer is an instrument in which the known weight of a column of mercury is placed in opposition to that of the

atmosphere, the prime purpose being to ascertain the varying pressure of the latter. The readings are taken in inches of mercury which represents the difference in levels between the surfaces of the mercury contained in the cistern and the indication as noted in the tube. It should be understood that the upper end of the tube is sealed; also that the empty space in the upper part thereof is a vacuum, and that the pressure of the atmosphere is acting on the surface of the mercury into which the lower end of the tube is immersed. Knowing the weight of a cubic inch of mercury, and also, being conversant with the manner in which pressures are transmitted by liquids and gases we may readily recognize the principle which is involved and also understand how the reading of the barometric inches can be converted into pounds pressure per square inch.

Q. 27. (1898-9.) What impression should the reading of a pressure gauge convey to the engineer?

Ans. 27. The reading of the pressure gauge should convey to the engineer a realization that the force indicated in pounds pressure per square inch is acting with that intensity upon all the surfaces or areas which are accessible to the pressure under notice of the gauge. It should not escape us, however, that considered in the sense of causing rupture—the ends of a string must be pulled in opposite directions to produce a strain equal to the force applied at one of the ends.

Q. 28. (1898-9.) In a concise yet comprehensive manner explain the value of the British Thermal Unit of heat and the connection and importance of this unit in the measurement of heat exchange.

Ans. 28. The British Thermal Unit of heat, usually abbreviated to B. T. U., is a measure which defines heat as a quantity irrespective of temperature. The unit is based on and is equivalent to the amount of heat required to raise one pound of water through one degree of Fahrenheit.

Similar quantities of different substances require varying quantities of heat to produce the same temperature; the B. T. U. therefore establishes a basis for intelligent comparisons and is used in computing all questions relating to the transmission or absorption of heat.

There is believed to exist a definite relation between heat and mechanical energy; this relation expressed in foot pounds has been determined experimentally and is known as the "Mechanical Equivalent of Heat" that is, 778 foot pounds of work done, being regarded as the equivalent of one B. T. U.

INTRODUCTION TO QUESTIONS 31 TO 42 (1898-9).

ANOTHER STEP IN MATHEMATICS.

The value and need of good, sound arithmetical knowledge, ranging upward from the simplest propositions, has been accorded proper recognition in these columns. The fact that it is quite possible to "get along" without such further embellishment of the science, as are embraced in the higher branches of mathematics, has also been conceded.

This admission, while pleasing, perhaps, to those preferring to evade the more advanced methods of calculating, must be qualified, however, by the further assertion, that the "kind" of progress which is possible under such limitations, may be likened to the difference in travel, between the stage coach of old, and the "flying" express trains, now so familiar in modern railroading. By either method, of course, the traveler starts with the expectation of reaching his destination,

but where the latter mode is available, it is safe to say, that usually the business may be done and time enough remains to forget about the transaction, before the ancient form of conveyance could be "due" at the further end of the route.

For covering short, easy distances, the simple and more primitive vehicle continues to fit conditions not requiring the excessive elaboration of a railway system; so with propositions of a mathematical nature—easy problems are best solved by simple methods, but when the elements of the case are quite intricate, the question resolves itself into one of two things, i. e., a solution, acquired by a tedious, slow and laborious process, or the same results, reached with ease, rapidity and dispatch.

As the railway emanated from the older and slower methods of transportation, so are the higher mathematics evolved from the fundamental reasoning on which arithmetic is based; both are representative of progress, and as the business people look to the former as the means of facilitating trade, so should progressive engineers view the latter, for algebraic expressions will continue to be used by advanced writers, and to expect anything but this is fully as unreasonable as a demand for a general return to customs and practices which are regarded as obsolete.

It would be a difficult matter to answer satisfactorily "how far" the stationary engineer should pursue mathematics, or to say definitely how little is necessary to serve his purpose; each individual, rather, should estimate his needs, and referring more particularly to such engineers, not favored with an early training, the deficiency should be made good as fast as it is found that a lack of such knowledge acts as an impediment to progress.

Personal experience is one of the best ways to gain knowledge—but when dependent on this alone, progress is slow, because life is too short to acquire all things by actual contact; advancement follows with more certainty and greater rapidity to those who aim to couple with their own practice the facts garnered by the multitude of other patient workers in the same field.

To distribute accumulated experience is the object of the mechanical press; it is the object of all literature which pertains to the work of the engineer or the artisan, and is the prime object of this, and other, associations organized for the dissemination of technical knowledge.

To profit by reading, it is evident that the language used should "strike home," as published rules and deductions are usually expressed algebraically, it follows that the reader should be conversant with the mathematical signs ordinarily used and should also be familiar with simple equations, for seldom do the most useful formula exceed the scope of this ready method of stating concisely the mathematical operations to be performed on the quantities which represent the elements entering into the problem.

As expressed verbally, or in written language, every rule recites the arithmetical operations to be performed with certain known quantities, in order that the value of some other may thereby be determined.

Let us assume, now, that we are charged with the duty of investigating the strength of a double riveted lap joint and let the mathematical reasoning concerned therewith serve to make plain the operations usually involved in any formula, when set forth in the form of a simple algebraic equation.

In this particular case, the elements entering into this problem are as follows:

The tensile strength of the plate per square inch of section, the thickness of plate in inches and the portion of the plate remaining unimpaired between rivet holes; the product of these three factors represents the ultimate strength of the joint, as far as the plate has to do with the question.

On the other hand, we have two rivets, corresponding to the above section of plate; these have a certain shearing resistance per square

inch of suction; the combined area of rivets, taken in square inches and multiplied by their shearing strength, gives the ultimate holding power of this second element of the joint.

A concise writer would probably express the foregoing elements as follows, representing each of the several factors by means of a single letter, thus:

$T =$ Tensile strength of plate per square inch.
$p =$ Thickness of plate.
$r =$ Length of plate remaining between rivet holes.
$A =$ Area of the rivets.
$s =$ Shearing strength of rivets per square inch.

Then, $T \times p \times r = A \times s$, is the equation, covering the theory of the riveted joint; interpreted, it reads as indicated in the preceding paragraphs, i. e., the tensile strength of the plate per square inch (T) multiplied by the thickness of the plate (p) and again multiplied by the length of the plate remaining between rivet holes (r) gives a certain product, which varies of course according to the values which may be given or assigned to each of the several factors.

Now if this product is found equal to the value of the area of the two rivets which serve to hold the above section of plate when their combined area (A) is multiplied by (s) their shearing strength per square inch, we may conclude that the joint is at its best, for it is evident that each side, or element, is affording exactly the same resistance to a rupturing force.

As written, the equation $T \times p \times r = A \times s$, is general, i. e., it leaves the actual value of each factor to be found and substituted by the person making practical use of the rule, hence if the several dimensions and the strength of the plate and rivet are known, and after performing the operations indicated, it is found that one is greater or less than the other, the fault is not with the equation, but with the joint, for the proposition may be such that the products found do not maintain the required equality which the theory of the case demands.

The investigation of a given joint, according to the method outlined, is simply "weighing" the question in the algebraic "balance," called an equation, and in this connection, it is necessary to firmly fix in mind the true meaning of the mathematical sign of equality, thus, $=$.

The sign of equality means just what its name indicates, and when it appears in a mathematical proposition, it serves as an indication that the values of the numbers, or quantities, between which it is placed, are equal, or the equivalent of one another—just as the pans of the "old time" balance come to a level when both sides are equally weighted.

Equations are solved by performing certain operation on its terms, the object being to find the value of unknown factors in the problem, by a method of reasoning directed against others which have a known or assigned value. In a general way, the process may be illustrated by assuming the quantities on each side of the sign $=$, to be weights, laying on the pans of an ordinary beam balance. The weights being equal, the pans stand at a level and so they will remain, provided equivalent measures only are added, or taken from either side at the same time.

Let us now again take up the general equation noted in connection with the theory of riveted joints; where $T \times p \times r = A \times s$. Assume the factors $p \times r$, to have a balancing value, the exact amount of which we need care nothing about. Simply to illustrate the proposition, however, we say that $p \times r$ represents half the weight contained in the left hand pan of the balance. We can remove this half of the weight from the right side and not destroy the equilibrium of the balance, provided the weight in the left hand pan is also divided or diminished by "half." A little reasoning now makes evident the fact that $p \times r$, taken from the right hand side of the equation and used as a divisor against

the terms appearing on the right, will change the reading from

$$T \times p \times r = A \times s \text{ to } T = \frac{A \times s}{p \times r.} \qquad (1)$$

Further investigation will prove that this operation has in no way disturbed the equality between the two sides; that is, the pans of the balance remain level; we have gained an important point, however, by thus solving "T" and by similar reasoning we deduce.

$$p = \frac{A \times s}{T \times r} \qquad (2)$$

$$r = \frac{A \times s}{T \times p} \qquad (3)$$

also,

$$\frac{T \times p \times r}{A} = s \qquad (4)$$

$$\frac{T \times p \times r}{s} = A \qquad (5)$$

It will be noted the original equation has undergone five variations, that is, each factor has been arranged to stand alone in some one of these, hence if the value of any four of the five are known, the proper and corresponding value to be assigned to the one which is sought, can be readily determined by performing the operations indicated, substituting for the letters the numerical values which they are representative of; in other words, with the aid of a little mathematical reasoning, differing but slightly from the kind ordinarily used, the theory of a riveted joint have been converted into five rules. These five rules in this form, occupy but little space and answer effectually every question that can be raised in connection with the subject to which they pertain.

If it be a question of plate thickness, against the other values of a joint, Equation (2) is used reading thus: thickness of plate (p) equals, (=) product of rivet area and shearing strength of same, divided by the product of tensile strength of plate and length of unimpaired plate, between rivet holes, and so on.

It is not the object of this article to instill more than a mere elementary idea of the higher mathematics, neither has it been the aim to deal particularly with the subject of riveted joints, for it should be understood the principle explained has a wide and general application. Neither of the foregoing subjects can be administered in a single heroic dose; if, however, the importance of this additional step in mathematics is made more apparent by the language here recorded, the object in view will be quite fully accomplished. C. H. F.

Q. 31. (1898-9.) Gravity is a force, acting at all distances and tending to attract mutually, all bodies in the universe.

Give the law of gravity and state by whom it was first enunciated.

Ans. 31. Gravity is an attraction common to all material substances; the law of universal gravitation was discovered by Sir Isaac Newton and is as follows: "The force of attraction between bodies of matter is in exact proportion to their mass and inversely as the square of their distance apart."

The first of these propositions is quite plain; according to the other, the attractive power diminishes in the same proportion as the "square" of the number which expresses the increase of distance. Thus if the distance is doubled the attraction is lessened fourfold, because $4 = 2 \times 2$ and is the square of two, etc.

Q. 32. (1898-9.) What common instrument serves to show the direction in which gravity acts and what does this indicate to the mechanic?

Ans. 32. The plumb line and "bob" is a common instrument which shows the direction in which the force of gravity acts. To the mechanic it indicates a true perpendicular; it is evident, however, that no two such lines can be called strictly parallel, but for all the ordinary purposes of a mechanic, they may be so considered.

Q. 33. (1898-9.) Is the force of gravity constant; i. e., does the weight of a body vary according to its position with reference to the surface of the earth?

Ans. 33. Gravity is constant in the sense that its force is always acting. "Weight" is simply a measure of the force of gravity and serves to indicate the intensity of attraction at or near the surface of the earth and at which point is realized the maximum effect or greatest weight.

At the earth's center weight is nullified and becomes manifest according to the following laws of weight:

Moving outward from the earth's center, weight increases as the distance from the center increases.

Above the surface of the earth weight decreases as the square of the distance increases. Therefore, whenever the distance between two bodies varies to a sensible amount, gravity must be considered as a variable force.

Q. 34. (1898-9.) The "center of gravity" is a point upon which a body balances in every position. What is the difference between stable and unstable equilibrium?

Ans. 34. When a change in position or a slight displacement tends to elevate the center of gravity the body so moved tends to return to its original position and it is then said to be "stable" or in a state of stable equilibrium. When, however, the center of gravity is above the point of support and the shape of the body is such, that a jolt is likely to throw the line of direction outside of its base, then we have an unstable body or one likely to fall because of the constant tendency of the center of gravity to seek a position nearest to the point of support.

Q. 35. (1898-9.) Explain the difference between a constant or uniform rate of motion and motion uniformly "accelerated."

Ans. 35. "Uniform motion" means equal spaces described in equal time; that is, the "rate" being always the same. If the body describes a greater space in each successive movement the motion is "accelerated"; on the other hand, if the spaces be less, motion is said to be "retarded."

FALLING BODIES.

First law of falling bodies.

The space described by a falling body, in any given second, is equal to the product of twice the number of seconds, minus one, times the space described the first second.

Thus, a body will fall during the sixth second, viz: $2 \times 6 = 12$ and 12 minus $1 = 11$.

Space described the first second is 16.08.

Then $16.08 \times 11 = 176.88$ feet.

Second law of falling bodies.

The velocity acquired by a falling body at the end of any given second is equal to the product of the number of seconds into twice the space described the first second. Thus, the velocity attained at the end of the sixth second is $32.16 \times 6 = 192.96$ feet.

Third law of falling bodies.

The total space described by a body at the end of any given second is equal to the product of the square of the number of seconds into the space described the first second.

Thus, the total fall during six seconds is $16.08 \times 36 = 578.88$ feet.

Q. 36. (1898-9.) By whom were the foregoing laws determined and under what conditions are they true?

Ans. 36. The "Laws of Falling Bodies" as noted above were discovered by Galileo.

The laws assume that only the force of gravity is acting on the falling bodies; retardation due to resistance of the air or other influences are not considered, as such are always variable and cannot be allowed for in a single broad rule.

Falling in a vacuum the lightest substance partakes of the same rate of motion and drops just as promptly as the heaviest metals.

An unretarded falling body is an example of accelerated motion as may be noted from the various examples given in Q. 36 and 37.

Q. 37. (1898-9.) Knowing the laws of the falling bodies as given, how would you reason therefrom the final velocity acquired by a body falling through a space of 231 feet?

Ans. 37. In the absence of a specific rule, but knowing the laws of falling bodies, an answer to the proposition embodied in Question No. 37 is obtained by reasoning as follows:

Wanted—"the final velocity acquired by a body falling through a space of 231 feet."

According to the second law of falling bodies the velocity acquired at the end of any given second of time is 32.16 times the number of seconds and $V = 32.16 \times t$, is an equation which expresses that fact.

The proposition is to find the value of V, but in order to do this it is evident that a numerical substitute must be found for "t," which in this case stands for "seconds" during which the body is falling.

From the third law we deduce: $h = t^2 \times 16.08$, which means "h," the total height fallen, equals the product of the square of the time and the space traversed the first second.

Transposing the equation:

$$t^2 = \frac{h}{16.08} \qquad t = \sqrt{\frac{h}{16.08}}$$

Hence the value of "t" is equal to the square root of the distance "h" divided by 16.08. The expression

$$\sqrt{\frac{h}{16.08}}$$

can therefore be used as a substitute for "t" in the first equation, thus:

$$V = 32.16 \times \sqrt{\frac{h}{16.08}}$$

For the case in hand the true value of "h" is 231 and inserting this, we have

$$V = 32\ 16 \times \sqrt{\frac{231}{16.08}} = 121.88 \text{ feet.}$$

making the value of "h" = 1, we establish a general rule, viz:

$$V = 32.16 \times \sqrt{\frac{1}{16.08}}$$

which is equivalent to

$$V = 8.02 \times \sqrt{h}$$

Using this for the present proposition gives:

$$8.02 \times \sqrt{231} = 121.88 \text{ feet.}$$

So also does the more general rule:

$$V = \sqrt{2gh} = 121.88 \text{ feet.}$$

all of which verifies the correctness of the reasoning and indicates that principles, well fathomed, are quite independent of fixed rules.

Q. 38. (1898-9.) Which of the values given in the preceding laws do you recognize as the "increment of velocity" due to gravity? What small letter of the alphabet is generally used to represent this value, when such enters into a proposition which is expressed algebraically?

Ans. 38. 32.16 is a quantity well known as the "increment" of velocity. This value is slightly variable for different parts of the globe, and it is customary therefore to represent it by the small letter "g" in all general formulae in which it occurs as a factor.

Q. 39. (1898-9.) The specific gravity of a substance is expressed by figures which represent the relative or proportionate weight of that substance as compared with an equal bulk of some other which is fixed upon as a standard.

Name the standard substances usually assumed and explain how to determine the weight of a cubic foot of metal when its specific gravity is given at 7 7/10. What metal is probably referred to?

Ans. 39. Water at 62° Fahr., weighing 62.355 pounds per cubic foot, is the standard usually referred to, in connection with specific gravity.

For gases, the density of atmospheric air is made the basis of comparison.

The weight of a cubic foot of any substance may be found by multiplying its specific gravity, by the weight of a like volume of water; hence if 7.7 represents the S. G. then $62.355 \times 7.7 = 480$. The product corresponds with the weight of a cubic foot of wrought iron.

Q. 40. (1898-9.) What constitutes a "buoyant" substance and what law governs the degree of submersion of a body placed in water?

Ans. 40. Any solid, which weighs less, volume for volume, than the fluid in which it is immersed is said to be a "buoyant substance."

The law of submersion is that an immersed body loses an amount of weight, equivalent to the weight of the fluid it displaces.

Q. 41. (1898-9.) State what proportion of a timber, having a cross section of 12 by 12 inches, will remain above water, when its specific gravity is 0.5. How much additional weight must probably be added for every foot of its length, to cause it to sink until submerged?

Ans. 41. The specific gravity of timber being .5, its weight per cubic foot is $62.5 \times .5 = 31.25$ pounds or just half the weight of like volume of water. In accordance with the law quoted in the preceding case and noting the proportionate weights of the water and the timber, it is evident that one-half of the latter will remain above water and if its section is $12'' \times 12''$ an additional load of 31.25 pounds on every foot of its length will be required to balance the "buoyant effort" due to keeping the timber down on the water's surface.

Q. 42. (1898-9.) Explain the instrument known as the Hydrometer.

Ans. 42. The hydrometer is an instrument devised for determining the density of liquids. The graduations follow an arbitrary scale of degrees in Baume's and other instruments. The hydrometer really indicates the specific gravity of fluids and its scale can be arranged to read that way directly, or the arbitrary scale readings in degrees, may be converted into specific gravity by reference to the proper tables. The buoyant power of liquids varies with their weight or density and this is the principle made use of in the hydrometer. The instrument is marked at 0 or zero when immersed in water and the graduations running both ways from this point indicate a greater or lesser density when the instrument is immersed in the liquid which is to be tested.

PREFACE TO QUESTIONS OF 1899-1900.

FALLING BODIES.

To the progressive engineer, a thorough knowledge and understanding of this subject is certainly advisable. All computations in relation to bodies in motion, in their different characteristics, are affected by these rules, and without a knowledge of these principles one is in the dark why certain formulæ and rules are given.

I trust that a few questions on the subject will in no wise appear as a bugbear to our members who are earnestly seeking for a higher standard of improvement, not only in their manual training but in their social life, and I trust that those who are willing to work will be amply repaid for the time spent.

Refer back to last year's elementary course and refresh your mind on the treatment of the laws of motion, etc., and then grapple with the few questions of this year. Some standard work, for reference, should also be in the hands of all engineers.

"Acceleration." When an unrestricted force, acting upon a body, sets it in motion (i. e., gives it velocity), in the direction of the force, this velocity increases as the force continues to act, each equal interval of time (if the force remains constant) bringing its own equal increase of velocity. Thus, if a stone be let fall, the force of gravity gives to it, in the first inconceivably short interval of time, a small velocity downward. In the next equal interval of time it adds a second equal velocity, so that at the end of the second interval the velocity of the stone is twice as great as at the end of the first one, and so on.

We may divide the time into as small intervals as we please, and each such interval, the constant force of gravity gives to the stone an equal increase of velocity.

The rate of acceleration is the acceleration which takes place in a given interval of time, usually one second.

The unit rate of acceleration is that which adds unit of velocity in a unit of time, or when English measures are used, one foot per second per second.

For a given rate of acceleration the total accelerations are, of course, proportional to the times during which the velocity increases at that rate.

Laws of acceleration:

First—When the forces are equal the rates of acceleration are inversely as the masses.

Second—When the masses are equal the rates of acceleration are directly as the forces.

We thus arrive at the principle that, in any case, the rate of acceleration is directly proportional to the force and inversely proportional to the masses. Hence, if we make two forces proportional to two masses, the rates of acceleration will be equal; or for a given rate of acceleration the forces must be directly as the masses.

Time and space in our paper would not permit me to extend this study in detail, yet I will call your attention to some headings which should be carefully studied and thoroughly understood. For my own part, I regard the laws of falling bodies one of the most interesting studies that I have ever taken up. I will call our attention to:

The constant force of gravity; the acceleration of gravity; the relation between force and mass; the unit of mass impulse. Up to this point we should know definitely what to çonsider as the unit of velocity, force, mass and time. From this knowledge we will find that:

$$\text{Vel.} = \frac{\text{force} \times \text{time}}{\text{mass}}$$

$$\text{Force} = \frac{\text{velocity} \times \text{mass}}{\text{time}}$$

$$\text{Mass} = \frac{\text{force} \times \text{time}}{\text{velocity}}$$

$$\text{Time} = \frac{\text{mass} \times \text{velocity}}{\text{force}}$$

Also force $\times$ time $=$ mass $\times$ velocity.

This is simply a problem of four factors, having three of them given to find the fourth, which by transposition we see are easily obtained.

Forces in opposite directions; inertia and the densities of masses should be carefully investigated. Force in relation to work and so on until you arrive at the direct laws of falling bodies, which at some future time may be fully explained to you.

Q. 61. (1899-1900.) Having the temperature of sensible heat of steam given, give the rule for finding the total heat of the steam. Illustrate with an example expressed in formula.

Ans. 61. Using Kent for authority, the total heat of saturated steam is found by first subtracting from the temperature of a given pressure, 32°, and multiplying the remainder by .305 (the specific heat of saturated steam), and to the product add 1091.7.

Example:

When $H =$ total heat, and $t =$ the temperature.

Then $H = .305\ (t - 32°). + 1091.7$.

The temperature or sensible heat of steam at 70 lbs. g.p. is 316.1°.

The total heat equals H. Then, $H = .305\ (316.1° - 32°) + 1091.7 = 1178.3$ B. T. U.

Q. 62. (1899-1900.) What is the total heat of steam at 100 lbs. gauge pressure? Also the latent heat?

Ans. 62. The sensible heat of steam 100 lbs. g.p. is 337.8° F., and the total heat, using the above formula (Kent's) where

$H = .305\ (t - 32°) + 1091.7$.

$H = .305\ (337.8 - 32) + 1091.7$.

$H = .305\ (305.8) + 1091.7$.

$H = 93.27 + 1091.7$.

$H = 1185.0$, or the total heat of steam at 100 lbs. g.p.

For the latent heat of this given pressure (100 lbs. g.p.) using "Clark's formula" for finding the latent heat of steam at any given temperature. Where $L =$ latent heat; $t =$ temp. of the steam.

$L = 1092.6 - .708\ (t - 32°)$

$L = 1092.6 - .708\ (337.8° - 32°)$

$L = 1092.6 - (.708 \times 305.8)$

$L = 1092.6 - 216.5$.

$L = 876.1$ B.T.U., or the latent heat of steam at 100 lbs. g.p.

Q. 63. (1899-1900.) If the steam in the boiler is 270° and the feed water is 110°, how many units of heat will be necessary to add to the water to turn one pound of it into steam?

Ans. 63. Using "Kent's formula" the number of heat units to be added will be.

$.305\ (t—32°) + (1091.7—110) = .305\ (270°—32°) + 981.7 = (.305 \times 238) + 981.7 = 72.59 + 981.7 = 1054.29$ heat units to be added.

Q. 65. (1899-1900.) Which is the better conductor of heat, dry or moist steam? Why?

Ans. 65. Moist steam is the better conductor of heat. Dry steam is a poor conductor of heat, as compared with liquid water, or moist steam, for after moist steam has received enough heat to make it dry, or nearly so, it receives additional heat very slowly.

Q. 75. (1899-1900.) Does the change from water to steam, by the application of heat, affect the relation of the particles of the fluid? What has this change to do in relation to power?

Ans. 75. As water, the particles are strongly cohesive; as steam, the particles are repellant. It is this repellant force existing among the infinitely small atoms of steam which appears to give the energy to the mass of steam and render it serviceable.

The fluid, as water, is inexpansive, but the change to steam, by the application of heat, gives it energy or ability to do work, by the reason of its great expansive or elastic tendency.

Q. 81. (1899-1900.) What letter of the alphabet denotes acceleration?

What is the rate of acceleration per second, in feet, of a body falling freely in vacuo, from a state of rest?

What is the total acceleration in feet at the end of one, two, three, four, five, six and seven seconds?

What will be the distance fallen from a state of rest at the end of each second (as above stated)?

What will be the distance fallen (as above stated) in feet between each consecutive second?

Ans. 81. Acceleration is denoted by the letter "g" and equals 32.2 feet.

A body, falling freely in vacuo from a state of rest, acquires, by the end of the first second, a velocity of about 32.2 feet per second; and in each succeeding second an addition of velocity, or acceleration, of about 32.2 feet per second.

In other words the velocity receives in each second an acceleration of about 32.2 feet per second, or is accelerated at the rate of 32.2 feet per second per second.

This rate is generally called simply the acceleration of gravity.

It increases from about 32.1 feet per second per second at the equator to about 32.5 feet at the poles.

These values at the sea level, but at a height of five miles above that level it diminishes by only one part in 400. For all practical purposes it may be taken at 32.2 feet.

The total acceleration in feet of a body falling in vacuo, from a state of rest, may be found by the following rule:

Rule:—g multiplied by the time the body was falling equals the total acceleration acquired at the end of that second.

The acceleration acquired end of—

1st second equals 32.2 feet.

2d second equals 64.4 feet.

3d second equals 96.6 feet.
4th second equals 128.8 feet.
5th second equals 161.0 feet.
6th second equals 193.2 feet.
7th second equals 225.4 feet.

The total distance fallen from a state of rest, at the end of each second, is found by the following rule:

Rule:—The square of the time of the falling of the body multiplied by $\frac{1}{2}$g.

A body will fall at the end of the—
1st second 16.1 feet.
2d second 64.4 feet.
3d second 144.9 feet.
4th second 257.6 feet.
5th second 402.5 feet.
6th second 579.6 feet.
7th second 788.9 feet.

The distance fallen in feet between each consecutive second is found by the following rule:

Rule:—g multiplied by the number of seconds the body was falling minus $\frac{1}{2}$ second equals the distance a body will fall from the end of one second to the end of the next succeeding second.

A body will fall, from rest in the—
1st second 16.1 feet.
2d second (or from the end of the first to end of second) 48.3 feet.
3d second 80.5 feet.
4th second 112.7 feet.
5th second 144.9 feet.
6th second 177.1 feet.
7th second 209.3 feet.

Q. 82. (1899-1900.) In answer to this question give the rule, or state in formula, what will be the acceleration acquired in a given time (from rest); in a given fall (from rest); in a given fall in a given time (from rest)?

What will be the time required for a given acceleration; for a given fall (from rest); for a given fall (from rest or otherwise)?

What will be the fall for a given time (from rest); required for a given acceleration (starting from rest); during any given second (counting from rest)?

Ans. 82. The acceleration acquired in a given time $=$ g $\times$ time.

In a given fall (from rest) $= \sqrt{2\text{ g}} \times$ fall.

In a given fall from rest in a given time $=$ twice the fall $\div$ time.

The time required for a given acceleration $=$ accel. $\div$ g.

For a given fall (from rest) $= \sqrt{\ }$ fall $\div \frac{1}{2}$ g, or fall $\div \frac{1}{2}$ final velocity.

For a given fall from rest or otherwise $=$ fall $\div$ mean velocity, or $=$ fall $\div \frac{1}{2}$ (initial vel. $+$ final vel.).

The fall in a given time (from rest) $=$ time $\times \frac{1}{2}$ final vel., or $=$ time$^2 \times \frac{1}{2}$ g.

For a given acceleration starting from rest $=$ acceleration$^2 \div 2$ g.

During any given second counting from rest $=$ g (number of seconds — $\frac{1}{2}$ second).

Q. 83. (1899-1900.) Does the resistance of air affect the strict accuracy of these rules? Does the specific gravity of different bodies affect their falling properties? How do these laws apply to bodies thrown upwards vertically in the air with a given velocity?

Ans. 83. Owing to the resistance of the air none of the above rules gives perfectly accurate results in practice, especially at great velocities. The greater the specific gravity of the body the better will be the result.

The air resists both rising and falling bodies. If a body be thrown vertically upwards with a given velocity, it will rise to the same height from which it must have fallen in order to acquire said velocity; and its velocity will be retarded in each second 32.2 feet per second. Its average ascending velocity will be one-half of that with which it started; as in all other cases of uniformly retarded bodies. In falling it will acquire the same velocity that it started up with, and in the same time.

Q. 84. (1899-1900.) The time a weight was falling (from rest) was seven seconds, what was the distance in feet, passed through? What was the distance at the end of the fifth second? What was the distance passed through between the sixth and seventh second?

Ans. 84. The distance the weight would pass through in 7 seconds would be $d = t^2 \frac{1}{2} g = 7^2 \times 16.1 = 49 \times 16.1 = 788.9$ feet ans.

Second condition $d = t^2 \frac{1}{2} g = 5^2 \times 16.1 = 25 \times 16.1 = 402.5$ feet ans.

Third condition $d = g\ (7 - \frac{1}{2}) = 32.2 \times 6\frac{1}{2} = 209.3$ feet ans.

In which d = distance fallen in feet.

t = time in falling in seconds.

g = acceleration in ft. per second.

Q. 85. (1899-1900.) What will be the impact (striking force) in foot pounds of a weight of 450 pounds with a given velocity of 80 feet per second?

Ans. 85. The energy exerted equals the work performed. The following rule describes how the energy of a moving body at a given velocity can be determined.

Rule:—The weight of the body in pounds multiplied by the velocity squared, and this product divided by twice the rate of acceleration (32.2) in feet per second equals the work performed, or energy exerted.

Stated in formula—

$$F = \frac{Wv^2}{2\,g} = \frac{450 \text{ lbs.} \times 80^2}{64.4} = \frac{450 \times 6400}{64.4} = 44721 \text{ ft. lbs.}$$

Thus $F = 44721$ foot pounds. Energy exerted, in which

F = force, or energy exerted.

W = weight of the body = 450 lbs.

v = velocity in ft. per sec. = 80 ft.

g = rate of accel. in ft. per sec. = 32.2 ft.

By another rule we find that the measure of actual energy is the product of the weight of the moving body multiplied by the height from which it must fall to acquire its actual velocity.

Let v = velocity in ft. per sec. and h = height, it must fall then according to the laws of falling bodies—

$$h = \frac{V^2}{2\,g} = \frac{80^2}{64.4} = 99.378882 \text{ ft.,}$$ or the height of the fall to acquire a vel. of 80 ft. per sec., then—

450 lbs. $\times$ 99.378882 ft. = 44721 foot pounds.

The same result as obtained by the first rule, or formula.

Q. 86. (1899-1900.) In raising a weight of 16,000 pounds by the aid of a screw jack, the screw ¼-inch pitch, or four thread to the inch

(barring friction) how many pounds pull must be applied to a bar 36 inches long from center of screw to center of pull? Approximately, what is the efficiency of a screw?

Let W=weight in lbs.=16000.x=power required, then mean circumference = 72 inches.

W:x :: π72 : ¼.

Substituting 16000 : x : : 3.1416×72 : ¼.

16000 : x : : 226.2 : ¼.

Then, as the product of the extremes 16000 × ¼ =4000, equal the product of the means (226.2) x, x = 4000 ÷ 226.2 = 17.6 lbs., the required power. Or, as the weight to be raised is to the power required to raise it in one revolution of the screw, so is the circumference of the circle described by turning of the lever to pitch of the screw.

In practice the screw is used as a combination of leverage with an inclined plane; a spiral inclined plane being formed by the threads of the screw. While the power applied to the lever which turns the screw moves around an entire circle, the body moves only the distance between the centers of two threads.

The friction of the screw (which under heavy loads becomes very great) has also to be overcome by the power; and this fact makes these calculations of but little use.

Q. 93. (1899-1900.) How many pounds of steam at 85 lbs. pressure per square inch (absolute pressure) will be required to raise the temperature of 760 lbs. of water from 58° F. to 164° F., the water and steam mingling freely together?

Ans. 93. The mixture of steam and water at a temp. of 164° F. contains 132.404 B. T. U.; at 58° F. water contains 26.007 B. T. U. 164° F. — 58° F. = 106° F., the difference in temperature of the water and the steam and water mixed. 132.404 B. T. U. — 26.007 B. T. U. = 106.397 B. T. U., the number of B. T. U. in 106° F. temp.

Therefore, the number of B. T. U. that each pound of water will absorb equals 106.397 B. T. U. 760 × 106.397 = 80861.72 B. T. U. equals the number required to raise 760 pounds of water from a temp. of 58° F. to 164° F.

The steam mingling with the water will give up its latent heat of evaporation, which, at a pressure of 85 lbs. absolute per sq. in., is 891.3 B. T. U. per pound.

It will also give up a portion of its sensible heat in falling from a temperature due to 85 lbs., which is 316° F. to a temperature 164° F.

Steam at 316° F. contains 287.022 B. T. U. (sensible).

Water at 164° F. contains 132.404 B. T. U. (sensible).

287.022 — 132.404 = 154.618 B. T. U. that the steam gives up in addition to its latent heat (891.3 B. T. U.), thus 891.3 + 154.618 = 1045.918 B. T. U. per pound of steam.

The number of pounds of steam required is equal to the number of B. T. U. absorbed by the water, 80861.72 divided by the B. T. U. given up by one pound of steam, 1045.918.

80861.72 ÷ 1045.918 = 77.31 pounds of steam required under conditions of question.

Formula—

$$S = \frac{W\,(t_2 - t_1)}{L + (t - t_2)} = \frac{760\,(164 - 58)}{891.3 + (316 - 164)} = 77.22 \text{ ans.}$$

In which—

S = steam required in pounds.

W = the water to be heated, 760 lbs.

t_1 = initial temp. of water = 58° F.

t_2 = final temp. of water = 164° F.

t = temp. of the steam at given press. 316° F.

L = latent heat of steam at given press. 891.3 B. T. U.

Q. 105. (1899-1900.) What is understood by the term "Mechanical Efficiency" of an engine?

By the term "Thermal Efficiency" of an engine?

What is the mechanical efficiency of an engine developing 500 I. H. P. and 425 brake H. P.?

What is the thermal efficiency of an engine using steam at 130 lbs. absolute pressure, exhausting at 6 lbs. absolute pressure per sq. in.?

Ans. 105. The "mechanical efficiency" of an engine is the ratio of the actual horse-power used in performing the work, to the indicated horse-power, or the mechanical energy, developed in the cylinder realized in useful work expressed in percentage.

Rule.—Multiply the actual horse-power by 100 and divide this product by the indicated horse-power and the quotient will be the mechanical efficiency, expressed in percentage.

The "thermal efficiency" of an engine is the ratio of the heat expended in the cylinder, is to the total heat entering the cylinder, or the total heat entering the cylinder that is used in performing work.

$$\frac{425 \times 100}{500} = 85 \text{ per cent mechanical efficiency.}$$

130 lbs. absolute = 347.1° F.

6 lbs. absolute = 170.1° F.

347.1 + 460 = 807.1, total temp. of steam entering cylinder.

170.1 + 460 = 630.1, total temp. of steam exhausting from cylinder.

807.1 — 630.1 = 177.0° F. that the temp. of the steam is reduced to in performing the work.

Then—

$$\frac{177 \times 100}{807.1} = 21.66 \text{ per cent thermal efficiency.}$$

Formula—

$$\frac{T - T^1}{T} \times 100 = \text{per cent T. E.}$$

Substituting—

$$\frac{807.1 - 630.1}{807.1} \times 100 = 21.66 \text{ per cent of thermal efficiency.}$$

T = absolute temp. of initial steam.

T^1 = absolute temp. of exhaust steam.

Q. 21. (1900-01.) What is the unit of heat and how is it expressed?

Ans. 21. Unit of Heat.—The British unit of heat, or British thermal unit (B. T. U.), is that quantity of heat which is required to raise the temperature of 1 pound of pure water 1° at or near 39.1° F., the temperature of maximum density of water.

The French thermal unit, or calorie, is that quantity of heat which is required to raise the temperature of 1 kilogramme of pure water 1° Cent., at about 4° Cent., which is equivalent to 39.1° F.

1 French calorie = 3.968 B. T. U.

1 B. T. U. = .252 calorie.

Q. 22. (1900-01.) What is the mechanical equivalent of heat?

Why do we say heat has a mechanical equivalent?

How many foot pounds are represented by each B. T. U., and what name is given to this equivalent?

Ans. 22. The Mechanical Equivalent of Heat.—Is the number of foot pounds of mechanical energy, equivalent to 1 British thermal unit? Heat has a mechanical equivalent because they both are mutually convertible.

Joule's experiment (1843-50) gave the figure 772, which is known as Joule's equivalent. More recent experiments by Prof. Rowland gives higher figures, and the most probable average is now considered to be 778. That is, 1 B. T. U. = 778 foot pounds, or 778 foot pounds is considered as the mechanical equivalent for 1 B. T. U.

Q. 23. (1900-01.) If one heat unit equals 778 foot pounds of energy, what decimal part of a heat unit does one foot pound represent?

How many heat units per hour, per minute, per second, are required for one horse-power?

One pound of carbon burned to $C\ O_2$ (carbon dioxide or perfect combustion) equals 14,544 heat units; what is the efficiency of one pound of carbon per horse-power per hour?

Ans. 23. If 1 heat unit equals 778 foot pounds of energy, 1 foot pound equals $1/778 = .0012852$ heat units.

1 H. P. = 33000 foot pounds per minute.

1 H. P. = 2545 B. T. U. per hour.

1 H. P. = 42.416 + B. T. U. per minute.

1 H. P. = .70694 B. T. U. per second.

1 pound of carbon burned to $C\ O_2 = 14544$ heat units.

1 pound of carbon per H. P. per hour $= 2545 \div 14544 = 17\frac{1}{2}$ per cent efficiency.

Q. 25. (1900-01.) What is thermal capacity, and what is the coefficient of thermal capacity?

Ans. 25. Specific Heat.—The thermal capacity of a body is the quantity of heat required to raise its temperature 1°.

The ratio of the heat required to raise the temperature of a given substance 1° to that required to raise the temperature of water 1° from the temperature of maximum density; 39.1° F. is commonly called the specific heat of the substance. or co-efficient of thermal capacity.

Q. 26. (1900-01.) How is the specific heat of a substance obtained or determined according to the method by mixture? Give formula for the same.

Ans. 26. Determination of Specific Heat.—Method by Mixture: The body whose specific heat is to be determined is raised to a known temperature, and then is immersed in a mass of liquid of which the weight, specific heat and temperature is known. When both the body and the liquid have attained the same temperature, this is carefully ascertained.

Now the quantity of heat lost by the body is the same as the quantity of heat absorbed by the liquid.

Let—

C = specific heat of the hot body;

W = weight of the hot body;

t = temperature of the hot body;

C^1 = specific heat of the liquid;

W^1 = weight of the liquid;

t^1 = temperature of the liquid.

T = temperature the mixture assumes.

Then, by the definition of specific heat, $C \times W \times (t - T)$ = heat units lost by the hot body, and

$C^1 \times W^1 \times (T - t^1) =$ heat units gained by the cold liquid.

If there is no heat lost by radiation or conduction these must be equal, and

$$C\ W\ (t - T) = C^1\ W^1\ (T - t^1) \text{ or, } C = \frac{C^1\ W^1\ (T - t^1)}{W\ (t - T)}$$

Q. 33. (1900-01.) How would you place a globe valve on a steam pipe with the pressure above or below the valve, and why?

Would you place the valve so the stem is in a vertical or horizontal position?

Ans. 33. A globe valve should be placed on a steam pipe with the pressure below the valve. There are opinions contrary to this, but it is believed that such opinions are entertained principally by cranks and those who like to be on the off-side.

It is advocated that the pressure being on top of the valve that it is not so liable to leak. This is erroneous. If the seat is cut a valve will leak regardless of the pressure.

Again, if the valve becomes detached from the stem with the pressure on top, operations have to be suspended until the valve is replaced or repaired. For convenience of packing the stem, the pressure should be placed on the under side of the valve.

It is proper to have the stems of the valves horizontal. This is also a matter of convenience for opening and closing and also avoids forming a water pocket.

Valves so placed that the stems hang down beneath the pipe is not good practice, and should be severely condemned.

Q. 35. (1900-01.) Describe the "steam loop," its uses and upon what does its action depend.

Furnish sketch.

Ans. 35. The "Steam Loop."—It is a system of piping by which water of condensation in steam pipes is automatically returned to the boiler.

In its simplest form it consists of three pipes, which are called the "riser," the "horizontal," and the "drop-leg."

When the steam-loop is used for returning to the boiler the water of condensation and entrainment from the steam pipe through which the steam flows to the engine cylinder, the riser is generally attached to a separator; this riser empties at a suitable height into the horizontal, and from thence the water of condensation is led into the drop-leg, which is connected to the boiler, into which the water of condensation is fed as soon as the hydrostatic pressure in drop-leg in connection with the steam pressure in the pipes is sufficient to overcome the boiler pressure. The action of the device depends on the following principles:

Difference of pressure may be balanced by a water column; vapors or liquids tend to flow to the point of lowest pressure; rate of flow depends on difference of pressure and mass; decrease of static pressure in a steam pipe is proportional to rate of condensation. In a steam current water will be carried or swept along rapidly by friction.

The water of condensation runs into a separator. The drip from the separator is below the boiler, and, evidently, were a pipe run directly to the boiler, we would not expect the water to return up hill. Moreover, the pressure in the boiler is say, 100 pounds, while in the separator it is probably about 95 pounds, due to the drop of pressure in the steam pipe, by reason of which difference the steam flows to the engine. Thus the water must not only flow up hill to the boiler, but must overcome the difference in pressure.

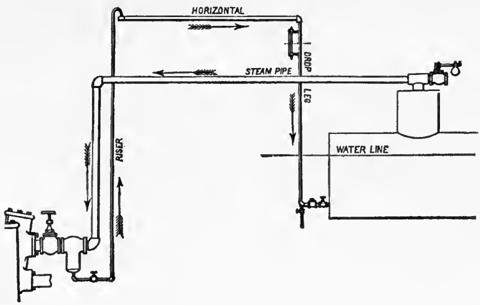
The device to return it must perform work, and in so doing heat must be lost.

The loop, therefore, may be considered as a peculiar motor doing work, the heat expended being radiation from the upper or horizontal portion.

From the separator or drain leads the pipe called the "riser," which at a suitable height empties into the "horizontal." This leads to the "drop-leg," connecting to the boiler anywhere under the water line. The "riser," "horizontal" and "drop-leg" form the loop, and usually consist of pipes varying in size from ¾-inch to 2 inches, and are wholly free from valves, the loop being simply an open connection from separator to boiler. (For convenience stop and check valves may be used, but they take no part in the loop's action.)

Suppose steam is passing, engine running and separator collecting water. The pressure of 95 lbs. at the separator extends back through the loop, but in the drop-leg meets a column of water which has risen from the boiler when the pressure is 100 lbs., to a height of about 10 feet; that is, to the hydrostatic head equivalent to the 5 lbs. difference in pressure.

Thus the system is placed in equilibrium. Now the steam in the horizontal condenses slightly, lowering the pressure to 94 lbs., and the



column in the drop-leg rises 6 inches to balance it; but meanwhile the riser contains a column of mixed vapor, spray and water, which also tends to rise to supply the horizontal as its steam condenses, and being lighter than the liquid water of the drop-leg, it rises much faster.

If the contents of the riser have a specific gravity of only .1 that of the water in the drop-leg, the rise will be ten times as rapid; and when the drop-leg column rises 1 foot the riser column will lift 10 feet.

By this process the riser will empty its contents into the horizontal, whence it is a free run to the drop-leg and thence to the boiler.

In brief, the above may be summed into the statement that a decrease of pressure in the horizontal produces similar effects on contents of riser and drop-leg, but in degree inversely proportional to their densities. When the condensation in horizontal is maintained at a constant rate sufficient to give the necessary difference of pressure, the drop-leg column reaches a height corresponding to the constant difference and rises no higher. Thus the loop is in full action, and will maintain circulation so long as steam is on the system, and the difference of pressure and quantities of water are within the range for which the loop is constructed.

No water should accumulate in the separator, as it is the mission of the loop to remove it before it assembles into a liquid mass.

It is here that constant and vigorous action is of great practical utility, enabling the loop to act as a preventive rather than a device for removing water after it has accumulated. The separator evidently must be of such form as to give the sweep toward and through the loop better opportunity to pick up the entrained water than is afforded by the current sweeping toward the engine, pump or steam using device. The loop action is practically independent of the distance the source of supply is above or below the boiler and also independent of the length of return. It is capable of handling such quantities of water as usually exist in steam systems. It is practically limited by excessive differences in pressures, and abnormal quantities of water.

The National Association of Stationary Engineers

ORGANIZED OCTOBER, 1882. INCORPORATED OCTOBER, 1892

Three hundred and eighty subordinate Associations with sixteen thousand members in forty-eight States and Territories

PREAMBLE.

This Association shall at no time be used for the furtherance of strikes, or for the purpose of interfering in any way between its members and their employers in regard to wages; recognizing the identity of interests between employer and employe, and not countenancing any project or enterprise that will interfere with perfect harmony between them.

Neither shall it be used for political or religious purposes. Its meetings shall be devoted to the business of the Association, and at all times preference shall be given to the education of engineers, and to securing of the enactment of engineers' license laws in order to prevent the destruction of life and property in the generation and transmission of steam as a motive power.

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1884.	James G. Beckerleg	Chicago, Ill.
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1896.	J. W. Lane	Providence, R. I.
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1899.	Herbert E. Stone	Cambridge, Mass.
1900.	P. E. Leahy	New York City
1901.	E. G. Jacques	Detroit, Mich.

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